EVALUATION OF INFRARED TREATMENTS FOR MANAGING ROADSIDE VEGETATION

Final Report

SPR 376

Oregon Department of Transportation

EVALUATION OF INFRARED TREATMENTS FOR MANAGING ROADSIDE VEGETATION

Final Report

SPR 376

by

Rob Edgar
Oregon Department of Transportation
Research Group
200 Hawthorne Avenue SE, Suite B-240
Salem OR 97301-5192

for

Oregon Department of Transportation
Research Group
200 Hawthorne Avenue SE, Suite B-240
Salem OR 97301-5192

and

Federal Highway Administration
400 Seventh Street S.W.
Washington, DC 20590

December 2000

Technical Report Documentation Page

1. Report No. FHWA-OR-RD-01-06	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EVALUATION OF INFRARED TREATMENTS FOR MANAGING ROADSIDE VEGETATION		5. Report Date December 2000 6. Performing Organization Code
7. Author(s) Rob Edgar, Research Coordinator Oregon Department of Transportation -- Research Group 200 Hawthorne Ave. SE, Suite B-240 Salem, Oregon 97301-5192		8. Performing Organization Report No.
9. Performing Organization Name and Address Oregon Department of Transportation Research Group 200 Hawthorne Ave. SE, Suite B-240 Salem, Oregon 97301-5192		10. Work Unit No. (TRAIS) SPR 376 11. Contract or Grant No. PSC 14549
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Group and 200 Hawthorne Ave. SE, Suite B-240 Salem, Oregon 97301	Federal Highway Administration 400 Seventh Street S.W. Washington, DC 20590	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Environmental concerns have prompted many agencies to seek alternatives to herbicides in controlling vegetation on roadway shoulders. This study was implemented to evaluate the potential for infrared technology to address this need. Infrared technology uses radiant energy to kill unwanted vegetation. Intense heat generated by liquid propane coagulates plant proteins and bursts cell walls, killing seedling plants and destroying the tops of established vegetation. Repeated treatments at regular intervals deplete the root reserves of established plants and leads to their decline and eradication. Infrared treatments were applied at three rates (8, 6 and 4 treatments/year) along Oregon highways from November 1996 through June 1999. These treatments were compared to shoulders treated with herbicides and to shoulders where vegetation was left unmanaged (controlled sites). Results suggest that infrared technology can keep vegetation under control on roadway shoulders.

17. Key Words VEGETATION MANAGEMENT, INFRARED, HERBICIDES, ROADSIDES, SHOULDERS		18. Distribution Statement Copies available from NTIS	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	20. No. of Pages 154	21. Price

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized ♲ Printed on recycled paper

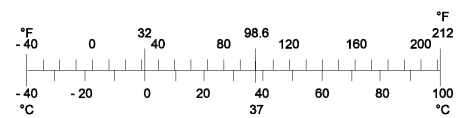
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	Inches	25.4	Millimeters	Mm
Ft	Feet	0.305	Meters	M
Yd	Yards	0.914	Meters	M
Mi	Miles	1.61	Kilometers	Km
		AREA		
in^2	Square inches	645.2	millimeters	mm^2
ft^2	Square feet	0.093	meters squared	M^2
yd^2	Square yards	0.836	meters squared	M^2
Ac	Acres	0.405	Hectares	Ha
mi^2	Square miles	2.59	kilometers squared	Km^2
		VOLUME		
fl oz	Fluid ounces	29.57	Milliliters	ML
Gal	Gallons	3.785	Liters	L
ft^3	Cubic feet	0.028	meters cubed	m^3
yd^3	Cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
Oz	Ounces	28.35	Grams	G
Lb	Pounds	0.454	Kilograms	Kg
T	Short tons (2000 lb)	0.907	Megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	Millimeters	0.039	inches	in
m	Meters	3.28	feet	ft
m	Meters	1.09	yards	yd
km	Kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	Hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	Milliliters	0.034	fluid ounces	fl oz
L	Liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	Grams	0.035	ounces	oz
kg	Kilograms	2.205	pounds	lb
Mg	Megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



***** SI is the symbol for the International System of Measurement

(4-7-94 jbp)

ACKNOWLEDGEMENTS

The author would like to thank the Technical Advisory Committee (TAC) members, ODOT maintenance crews and field evaluators for their efforts and support to this project:

- David Humphrey, Vegetation Management Coordinator (Retired), Maintenance Office, ODOT
- Bette Coste, Vegetation Management Coordinator, Maintenance Office, ODOT
- Jeff Moore, Maintenance Office, ODOT
- Mike Spaeth, District 8 Maintenance Office, ODOT
- Uwe Kuehn, Central Point Maintenance Crew, ODOT
- Everett Carroll, Grants Pass Area Maintenance Manager, ODOT
- Dennis Joll, District 5 Special Programs Coordinator, ODOT
- Jeff Smith, Environmental Section, ODOT
- Jeff Wheaton, Vegetation Control Coordinator, Josephine County Public Works
- Myron Shenk, Extension Pesticide Training Coordinator, Oregon State University
- Ivan Marrero, FHWA
- Paul Gunter, Williams Associates Against Herbicides & Pesticides (WAAHP)
- Laura Suverly, Crop & Soil Sciences, Oregon State University
- Daniel Jones, Oregon State University

The author would also like to acknowledge Greg Prull, IPM Associates, Inc., for providing the infrared treatments at the test plots, and for his support to this project.

PHOTO EXHIBIT

A color photo exhibit showing various infrared applications is available. For information contact: Greg Prull, IPM Associates, Inc., P.O. Box 21108, Eugene, OR 97402.
Phone: 541-345-2272. Email: ipmpg@efn.org

EVALUATION OF INFRARED TREATMENTS FOR MANAGING ROADSIDE VEGETATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PHOTOS/FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND

The Oregon Department of Transportation (ODOT) maintains 8,078 miles (13,005 km) of roadway and adjoining shoulders. Many of these areas include ditches, wetlands, erosion control and riparian zones. The methods used to control roadside vegetation include:

- Herbicides (contact, translocate and residual types),
- Mowing,
- Shoulder blading,
- Cultural re-vegetation and seeding,
- Hand labor, and
- Biological (insects, pathogens).

Of these, herbicides are the most cost-effective method. However, environmental rules, regulations and public concerns have prompted many agencies to seek alternate methods to herbicides.

In addition, there are also rules to control noxious weeds and promote natural vegetation. The proliferation of these rules has prompted many agencies to adopt an Integrated Vegetation Management (IVM) program. The IVM program is intended to coordinate decision-making action processes using the most appropriate vegetation control methods and strategy in an environmentally sound manner. This includes seeking cost-effective alternatives for vegetation control. The governing rules include the following:

- Federal Water Pollution Control Act – 1948
- Federal Clean Water Act – 1977 (33 U.S.C. 1251)
- Federal Insecticide, Fungicide and Rodenticide Act – 1972 (7 U.S.C. 136)
- Federal Endangered Species Act of 1973 (P.L. 93-205, 16 U.S.C. 1531 et seq.)
- Federal Noxious Weed Act – 1974 (7 U.S.C. 2801)
- Federal Wildflower statutes (23 U.S.C. 319)
- National Pollutant Discharge Elimination System (33 U.S.C. 1342)
- Presidential Memorandum on Environmentally and Economically Beneficial Landscaping – 1994 (Federal Register, Vol. 60, No. 154, August 10, 1995)
- Oregon Wildflower Protection Statutes – 1963, 1987 (ORS 564.020)
- Oregon Pesticide Control Act – 1973, 1995 (ORS 634.005)
- Oregon Weed Control Statutes – 1985, 1999 (ORS 570.500)
- Oregon Threatened or Endangered Wildlife Species Statutes – 1987, 1995 (ORS 496.171)
- Oregon Threatened or Endangered Plants Statutes - 1987 (ORS 564.100)
- Oregon Integrated Pest Management Laws- 1991 (ORS 634.650)

- Oregon Plan, Coastal Salmon Restoration Initiative – 1995 (ORS 541.405 & 1995 c.544 s.2)
- Oregon Pesticide Use and Reporting, Temporary Provisions – 1999 (ORS 634, c.1059 s.4)
- Oregon Plan for Salmon and Watershed (SB924 1997, HB3700 1997, Executive 99-01)
- Federal Executive Order on Noxious Weeds – 1999 (EO 13112)

Roadside vegetation is treated for a variety of purposes and may vary by highway class, traffic volumes, geographic settings, budget constraints and other factors. ODOT's general policy states that proper sight distance, control of noxious weeds and invasive species should be of primary consideration, and vegetation must be controlled to prevent interference with the proper operation and maintenance of the highway. In general, roadside vegetation maintenance is performed to:

- Preserve the structural integrity of the roadway pavement,
- Provide for surface drainage and subsurface drainage,
- Prevent pavement breakup caused by plants,
- Prevent the establishment and spread of noxious weeds and nuisance vegetation,
- Prevent wildfires,
- Provide clear emergency shoulder pull-outs for motorists,
- Maintain driver visibility of roadways, traffic control devices, guardrails and approaches,
- Reduce deterioration of roadside hardware, and
- Maintain aesthetics of landscape areas.

1.2 OBJECTIVES

The objective of this study was to determine if infrared technology could be a biologically, economically and environmentally viable component of an Integrated Vegetation Management (IVM) strategy for roadside vegetation management.

1.3 TASKS

The research study included 7 tasks. The tasks are discussed in the sections shown below:

- Literature Review.............................. Section 2.0
- Site Selection.................................... Section 3.0
- Develop Specifications...................... Appendix F
- Treatment Methods .... Section 4.0
- Field Evaluation Methods .... Section 5.0
- Analysis of Data .... Section 7.0
- Recommendations .... Section 9.0

2.0 LITERATURE REVIEW

2.1 LITERATURE REVIEW METHODS

A literature review was undertaken in 1996 to identify possible sources of information related to the objective of this study. The review was conducted using both specific and broad subject areas:

Specific Topic:	*Use of Infrared Burners for Control/Management of Roadside Vegetation/Weeds*
Broad Topic:	*Use of Heat or Burning or Thermal Action for Vegetation/Weed Control/Management*

The literature search employed several electronic search tools including the following:

- The Internet: The Alta Vista Search Engine
- Library Holdings Worldwide: WorldCat Database
- Other Databases: ArticleFirst; BasicBIOSIS; GEOBASE and the Expanded Academic Index of Journals and Magazines.

In addition, information and resources were also provided by IPM ASSOCIATES, INC., who has interests in infrared equipment.

2.2 SUMMARY OF FINDINGS

The search included foreign library material and Internet sites. Any English-language material would have been identified in the search; however, no search attempt was made using foreign languages. The literature review identified little information on the topic in the United States. Most of the relevant information was from Europe, particularly the Netherlands, Germany and France. Letters of inquiry were sent to essential European contacts but no responses were received.

The first company to manufacture infrared, vegetation management equipment was HOAF, a Dutch firm. They offer a line of equipment from small hand-pushed models to medium and large units that can be attached to tractors. The small- and medium-sized units are generally used in urban areas for weed control requirements associated with ornamental horticulture. The larger units are designed for agricultural purposes (debris removal and disease control in greenhouses, desiccation of potato plants prior to harvest and weed control in orchards). HOAF also produces a device for cleaning pavement cracks prior to sealing and a unit for controlling weeds growing in the pavement seams of curbs and gutters. Custom-built units have been used for a few years on the German and French railways.

In the United States, HOAF's hand models have been tested in a few small scale field trials (e.g., weed control in low-bush blueberries; weed control on gravel paths and running tracks; weed control in interlocking pavers; and total vegetation control in dense sod). While results were promising, evaluators indicated additional studies were needed to produce definitive information. In addition, tests suggested that more effective equipment could be developed, particularly with respect to the design of the tools and their intended application setting(s).

No documented evaluations in the United States or elsewhere were found to involve roadside vegetation management.

HOAF's primary business is industrial applications of infrared equipment and does business principally in Europe; it has no operations or sales in North America.

Sunburst, Inc., a company in Eugene, Oregon, provided the infrared unit used for this project. Sunburst is developing a line of infrared equipment for sale in North America.

3.0 SITE SELECTION

3.1 SITE SELECTION AND CHARACTERISTICS

Three physiographic sites were used in this study. The sites were located in rural areas of western Oregon between the Coast and Cascade mountain ranges. They were along two-lane asphalt highways with gravel shoulders. Figure 3.1 shows the general locations of the three test sites. The study began with infrared treatments at Site 1 in November 1996. Sites 2 and 3 were added in February 1998 to test different climates and vegetation. Site 2 was the most typical of Western Oregon climate. Table 3.1 gives a summary description of the test sites.

Figure 3.1: Test site locations

Table 3.1: Summary of Test Sites

Site number	Site 1		Site 2	Site 3
County	Josephine		Lane	Lane
Location	West of Provolt		South of Creswell	Blachly
Highway	Jacksonville Hwy, #272	Water Gap Rd, #258	Goshen-Divide Hwy, #226	Mapleton-Junction City Hwy, #229
Route	Ore 238	na	Ore 99	Ore 36
Milepost	7.0 - 12.0	0.0 - 1.0	7.65 – 10.68	28.19 - 32.0
Jurisdiction	ODOT	County	ODOT	ODOT
Traffic volume	5300 ADT @ MP 7.21 1600 ADT @ MP 11.88		3100 ADT	1000 ADT
Road alignment	Mixture of curves and ½ mile (0.8km) straight sections		Mostly straight	Mixture of curves and ¼ mile (0.4km) straight sections
Shoulder	Gravel, 4-8 feet wide (1.22-2.44m). Adjacent to ditch.		Gravel, 4-6 feet wide (1.22-1.83m). Adjacent to ditch	Gravel, 4-6 feet wide (1.22-1.83m). Adjacent to fill slopes, cuts or ditches.
Adjacent property	Small residential farmlands.		East side: railroad mainline parallel to road. West side: rural residences and businesses	Open farmlands at East and West ends, hilly forested terrain in middle.
Historical vegetation treatments	Treated annually with herbicides. In 10/98 a shoulder blading operation disturbed most of the test plots leaving very little vegetation.		Treated annually with herbicide.	Treated annually with herbicides up to 1995. Site received heavy flooding in spring 1996. From 1996-1997 herbicides were limited to spot spray use on noxious weeds. Site mowed down to 2-3” (50-75mm) in 3/98 in preparation of study.
Condition of Vegetation	Under control when study treatments began in 11/96. Appendix **B** lists the types of vegetation found.		Under control when study treatments began in 2/98	Dense growth of vegetation with spreading noxious weeds when study treatments began in 3/98
Annual rainfall	About 25” (630 mm)		About 46” (1170mm)	60-90” (1520-2290mm)
Min/Max Temperature	39-68°F (4-20 °C) (average annual, min-max)		40-64°F (4-18 °C) (average annual, min-max)	41-62°F (5-17 °C) (average annual, min-max)

For this study, sites with sufficient shoulder width were chosen to aid in the vegetation treatments and field evaluations. Sites were also selected with a consideration for the safety of operations by minimizing curves and short sight distances. Figures 3.2, 3.3, and 3.4 show the specific locations of Sites 1, 2 and 3, respectively.

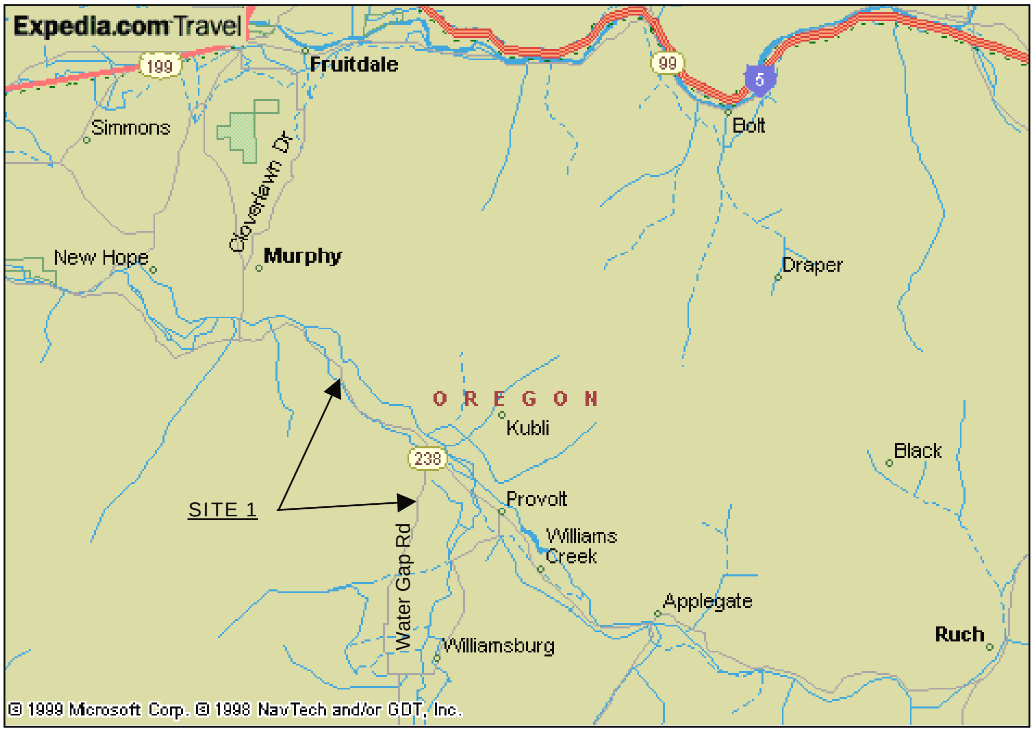


Figure 3.2: Site 1 map (Provolt)

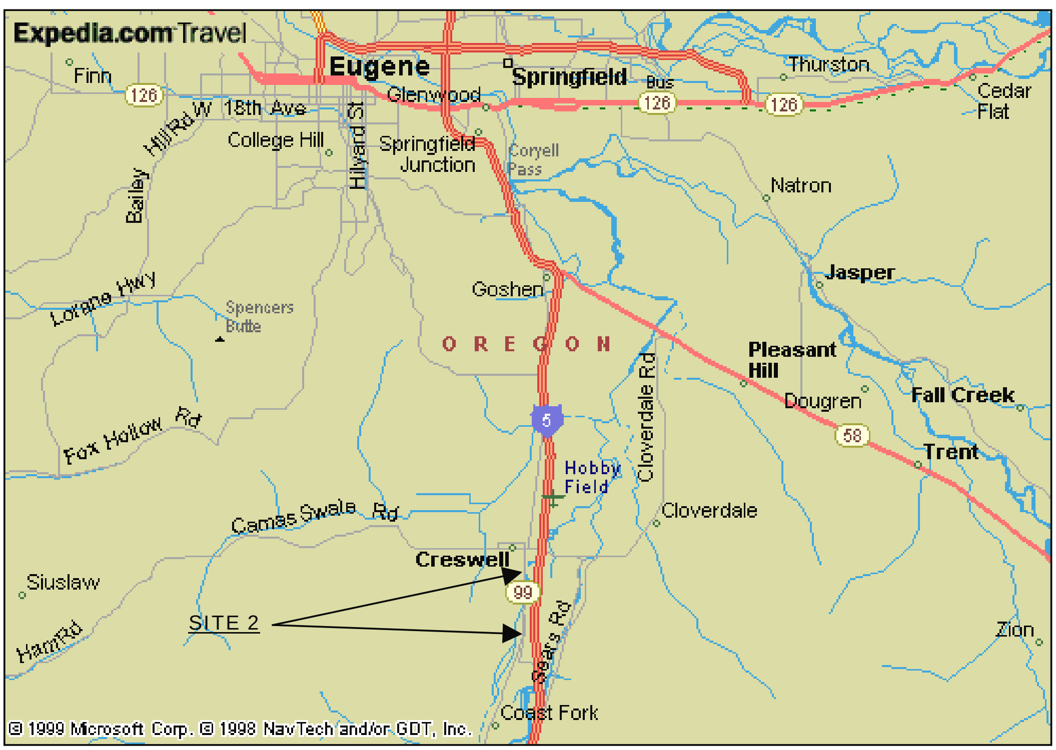


Figure 3.3: Site 2 map (Creswell)

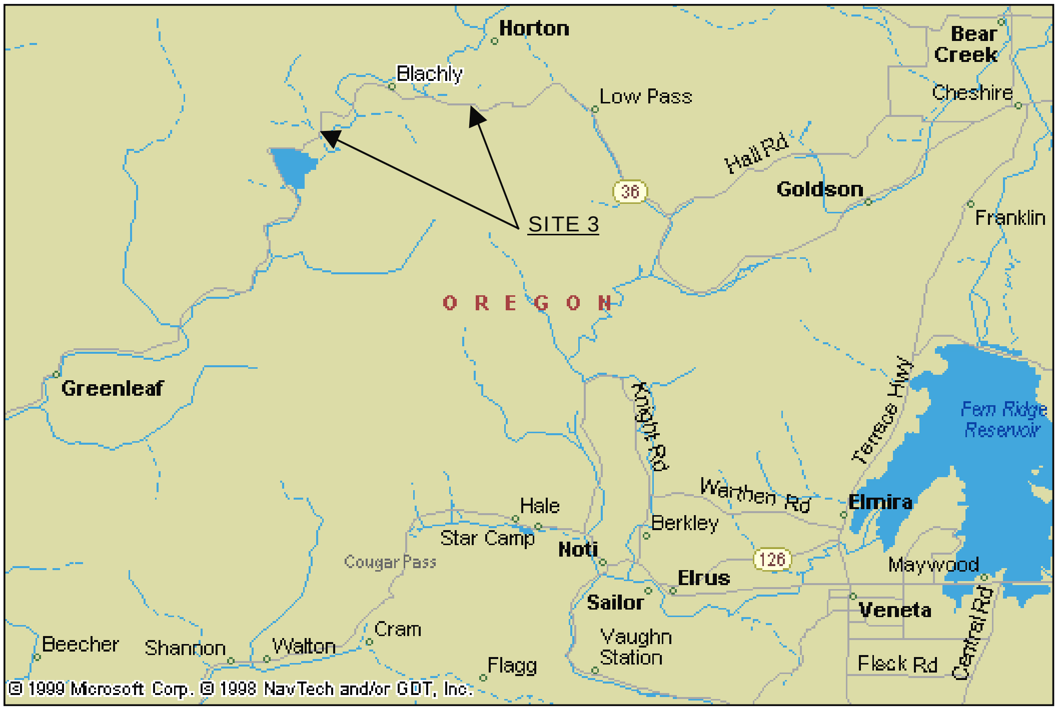


Figure 3.4: Site 3 map (Blachly)

3.2 PLOT DEMARCATION

Each site included plots for infrared treatments, herbicide treatments and an untreated control. Table 3.2 lists all the test plots evaluated in this study.

Site 1 – This site consisted of 32 plots, each ¼-mile in length (0.4km). Twelve plots were for infrared treatments, twelve were for herbicide treatments, and eight were for control. Each plot had twelve sub-plots as described in Section 5.1. The sub-plots were located at 100-foot (30m) intervals along the shoulder, with the first sub-plot starting 100 feet (30m) from the first milepost marker and ending 120 feet (37m) from the last milepost marker.

The plots were selected on a random basis from within a 10-mile (16km) roadway section. From this area, four one-mile (1.61km) sections were chosen at random. They were at Milepost (MP) 7-8, 8-9 and 11-12 on the Jacksonville highway and MP 0-1 on Water Gap Road. Each one-mile section was subdivided into the eight plots described above, consisting of three infrared plots, three herbicide plots and two control plots, all selected on a random basis.

Sites 2 and 3 were selected for the differences in climate and vegetation. The plots were not selected on a random basis; instead plot boundaries were set at recognized roadway features such as bridges or intersections. The plots ranged in length from 0.12 to 0.40 mile (0.19-0.64km) and were placed for efficient use of flagger and treatment operations.

Site 2 – This site had a mixture of grasses, broadleaf species and noxious weeds (field bindweed and knapweed). The site contained nine plots: four infrared, two herbicide, two control and one mow plot.

Site 3 – This site also had a mixture of grass, broadleaf and noxious weeds (horsetail, buckhorn plaintain, meadow knapweed and scotch broom). In addition it was considered “clean” of herbicide residue following a flood and three years without herbicide treatments. It also had heavy vegetation. The site contained eleven plots: five infrared, three herbicide, two control and one mow plot. Plot 3(B) had the thickest vegetation and was thus selected to receive eight infrared treatments a year.

See Appendix C for plot maps of the three sites.

Table 3.2: Research Test Plots

Site (plot)	Sub-plot spacing (feet)	No. of Sub-plots	Treatment Type *	Highway	Begin Mile Point	End Mile Point	Left/ Right **	Plot Length (miles)
Site 1 (Provolt)								
1 (1C)	100	12	Herb	Jacksonville (Hwy 272)	7.00	7.25	Lt	0.25
1 (1H)	100	12	I-8/6	Jacksonville (Hwy 272)	7.00	7.25	Rt	0.25
1 (1B)	100	12	I-4	Jacksonville (Hwy 272)	7.25	7.50	Lt	0.25
1 (1G)	100	12	Control	Jacksonville (Hwy 272)	7.25	7.50	Rt	0.25
1 (1A)	100	12	Herb	Jacksonville (Hwy 272)	7.50	7.75	Lt	0.25
1 (1F)	100	12	Herb	Jacksonville (Hwy 272)	7.50	7.75	Rt	0.25
1 (1D)	100	12	Cntrl	Jacksonville (Hwy 272)	7.75	8.00	Lt	0.25
1 (1E)	100	12	I-6	Jacksonville (Hwy 272)	7.75	8.00	Rt	0.25
1 (2H)	100	12	I-8/4	Jacksonville (Hwy 272)	8.00	8.25	Lt	0.25
1 (2A)	100	12	Herb	Jacksonville (Hwy 272)	8.00	8.25	Rt	0.25
1 (2F)	100	12	Herb	Jacksonville (Hwy 272)	8.25	8.50	Lt	0.25
1 (2B)	100	12	I-6	Jacksonville (Hwy 272)	8.25	8.50	Rt	0.25
1 (2G)	100	12	Cntrl	Jacksonville (Hwy 272)	8.50	8.75	Lt	0.25
1 (2C)	100	12	Herb	Jacksonville (Hwy 272)	8.50	8.75	Rt	0.25
1 (2E)	100	12	I-4	Jacksonville (Hwy 272)	8.75	9.00	Lt	0.25
1 (2D)	100	12	Cntrl	Jacksonville (Hwy 272)	8.75	9.00	Rt	0.25
1 (3B)	100	12	I-8/4	Jacksonville (Hwy 272)	11.00	11.25	Lt	0.25
1 (3E)	100	12	I-4	Jacksonville (Hwy 272)	11.00	11.25	Rt	0.25
1 (3A)	100	12	Herb	Jacksonville (Hwy 272)	11.25	11.50	Lt	0.25
1 (3F)	100	12	Herb	Jacksonville (Hwy 272)	11.25	11.50	Rt	0.25
1 (3C)	100	12	Herb	Jacksonville (Hwy 272)	11.50	11.75	Lt	0.25
1 (3H)	100	12	I-6	Jacksonville (Hwy 272)	11.50	11.75	Rt	0.25
1 (3D)	100	12	Cntrl	Jacksonville (Hwy 272)	11.75	12.00	Lt	0.25
1 (3G)	100	12	Cntrl	Jacksonville (Hwy 272)	11.75	12.00	Rt	0.25
1 (5D)	100	12	Cntrl	Water Gap Rd (Hwy 258)	0.00	0.25	Lt	0.25
1 (5G)	100	12	Cntrl	Water Gap Rd (Hwy 258)	0.00	0.25	Rt	0.25
1 (5A)	100	12	Herb	Water Gap Rd (Hwy 258)	0.25	0.50	Lt	0.25
1 (5H)	100	12	I-4	Water Gap Rd (Hwy 258)	0.25	0.50	Rt	0.25
1 (5C)	100	12	Herb	Water Gap Rd (Hwy 258)	0.50	0.75	Lt	0.25
1 (5E)	100	12	I-6	Water Gap Rd (Hwy 258)	0.50	0.75	Rt	0.25
1 (5B)	100	12	I-8/6	Water Gap Rd (Hwy 258)	0.75	1.00	Lt	0.25
1 (5F)	100	12	Herb	Water Gap Rd (Hwy 258)	0.75	1.00	Rt	0.25

Table 3.3 (continued): Research Test Plots

Site (plot)	Sub-plot spacing (feet)	No. of Sub-plots	Treatment Type *	Highway	Begin Mile Point	End Mile Point	Left/ Right **	Plot Length (miles)
Site 2 (Creswell)								
2 (A)	100	34	Herb	Goshen-Divide (Hwy 226)	7. 50	7.98	Lt & Rt	0.33
2 (B)	100	40	Mow	Goshen-Divide (Hwy 226)	7.98	8.36	Lt & Rt	0.38
2 (C)	100	36	Cntrl	Goshen-Divide (Hwy 226)	8.36	8.71	Lt & Rt	0.35
2 (D)	100	42	I-4	Goshen-Divide (Hwy 226)	8.80	9.20	Lt & Rt	0.40
2 (E)	100	42	I-6	Goshen-Divide (Hwy 226)	9.20	9.60	Lt & Rt	0.40
2 (F)	100	34	Herb	Goshen-Divide (Hwy 226)	9.69	10.03	Lt & Rt	0.34
2 (G)	50	34	Cntrl	Goshen-Divide (Hwy 226)	10.03	10.20	Lt & Rt	0.17
2 (H)	50	25	I-4	Goshen-Divide (Hwy 226)	10.20	10.44	Rt	0.24
2 (I)	50	25	I-6	Goshen-Divide (Hwy 226)	10.44	10.68	Rt	0.24
Site 3 (Blachly)								
3 (A)	100	22	Herb	Mapleton-Jct City (Hwy 229)	28.19	28.41	Lt & Rt	0.22
3 (B)	100	26	I-8	Mapleton-Jct City (Hwy 229)	28.41	28.66	Lt & Rt	0.25
3 (C)	100	34	I-6	Mapleton-Jct City (Hwy 229)	28.66	29.00	Lt & Rt	0.34
3 (D)	100	26	Cntrl	Mapleton-Jct City (Hwy 229)	29.11	29.36	Lt & Rt	0.25
3 (E)	50	26	I-4	Mapleton-Jct City (Hwy 229)	29.38	29.51	Lt & Rt	0.13
3 (F)	70	24	Herb	Mapleton-Jct City (Hwy 229)	29.51	29.67	Lt & Rt	0.16
3 (G)	100	26	Mow	Mapleton-Jct City (Hwy 229)	30.75	31.00	Lt & Rt	0.25
3 (H)	100	40	Cntrl	Mapleton-Jct City (Hwy 229)	31.00	31.38	Lt & Rt	0.38
3 (I)	50	24	I-6	Mapleton-Jct City (Hwy 229)	31.38	31.50	Lt & Rt	0.12
3 (J)	100	26	I-4	Mapleton-Jct City (Hwy 229)	31.50	31.75	Lt & Rt	0.25
3 (K)	100	26	Herb	Mapleton-Jct City (Hwy 229)	31.75	32.00	Lt & Rt	0.25

* I-4 = Infrared plots, 4 treatments per year
I-6 = Infrared plots, 6 treatments per year
I-8 = Infrared plots, 8 treatments per year
I-8/4 = Infrared plots, 8 treatments made in 1997, 4 treatments made in 1998 and 1999 (see Section 4.1.4)
I-8/6 = Infrared plots, 8 treatments made in 1997, 6 treatments made in 1998 and 1999 (see Section 4.1.4)
Herb = Herbicide plots
Cntrl = Control plot
Mow = Mowing plot

** Left and right designations are in relation to the direction of travel from low to high milepoints.

Table 3.3 shows the total number of sub-plots used in this study.

Table 3.4: Number of Plots and Sub-plots

Treatment Type	Number of Plots	Number of Sub-plots
I-4, I-8/4	10	191
I-6, I-8/6	10	197
I-8	1	26
Herb	17	284
Cntrl	12	232
Mow	2	66
Total	**52**	**996**

4.0 TREATMENT METHODS

4.1 INFRARED SECTIONS

4.1.1 Infrared Equipment

Infrared treatments were applied to the gravel shoulder of the road using a roadside infrared vegetation control unit (Figures 4.1). The prototype unit was manufactured by Sunburst, Inc. located in Eugene, Oregon. It applies an intense heat of about 1500º F (800º C), generated from a liquid propane fuel.

The radiating unit is a steel deck measuring 4 ft wide x 6 ft long (1.22 m x 1.83 m). The width of the treated area is the same as the deck width. The bottom of the deck travels 2 - 4 in. (50-100 mm) above the ground. The distance allows infrared heat to radiate down to the target vegetation with no equipment-to-vegetation contact. A hydraulic boom is used to maintain the proper deck elevation and is combined with a hydraulic pivot at the deck to match the slope of the road shoulder. The boom also provides some flexibility in moving the deck around obstacles such as sight posts, mailboxes and guardrail.

Figure 4.1: Infrared vegetation control unit

Treatments were applied at speeds of 1 - 3 mph (1.5 - 5 km/h) with an average speed of approximately 2 mph (3 km/h). Travel speed was influenced by plant type, maturity, density, moisture conditions, temperature, wind speed, wind direction and physical conditions along the road shoulder (e.g., presence of debris covering target weeds, slope changes, presence of rocks, limbs, sign posts, mailboxes or other impediments). Permanently moving the obstacles outside the treatment area would make the operation more efficient.

Fire control equipment accompanied the operation to extinguish ignited vegetation or debris. This consisted of a support truck with water tank, hose and spray nozzle (Figure 4.2). A laborer on foot with a shovel occasionally assisted in the fire suppression as needed.

Figure 4.2: Tractor with infrared unit, followed by support truck

A micro-irrigation system was available for the equipment but was not used on this project. The system applies water both fore and aft of the deck. Pre-wetting the vegetation is intended to increase the treatment effectiveness, whereas the post-treatment helps to reduce fire risk.

The infrared equipment and support truck operated from the travel lane for lack of adequate shoulder width. Flaggers were used because of the traffic volumes and/or limited sight distance. The fire control support truck doubled as a shadow vehicle to protect the workers and infrared equipment.

4.1.2 Theory of Infrared Radiation on Vegetation

According to Sunburst, Inc. the infrared radiation and intense heat coagulates the plant proteins and/or creates steam within plant cells, causing them to burst. The exposure either kills the plant outright (predominantly seedling vegetation and young plants) or severely damages their tops (established plants in particular). Extensive top damage disrupts the capacity for normal vegetative growth and forces injured plants to utilize root reserves to develop new stems and leaves. Depletion of these reserves and subsequent plant death is achieved by timely follow-up treatments. The number and timing of re-treatments is dependent on the plant type, maturity and density, as well as environmental conditions (e.g., soil type, moisture, temperature).

The extent to which treatments may have contributed to vegetation control objectives by damaging weed seeds on the soil surface was not distinctly measured.

4.1.3 General Observations

The constant speed of the infrared equipment prevented the ground surface from reaching excessive temperatures. Temperature readings were taken using a handheld infrared instrument. Temperatures immediately after treatment varied depending on initial ground temperature, moisture conditions and material comprising the road shoulder (e.g., gravel, soil and vegetation). For example, on a cool spring morning, the initial ground temperatures were typically 50°F (10°C) with or without vegetation. On dense moist vegetation, the temperature reached 150°F (66°C) immediately after treatment, then dropped to 120°F (49°C) after 5 seconds and 99°F (37°C) after 10 seconds. The temperature returned to normal after about a minute. By comparison, the temperatures on bare, course rock shoulder surfaces or asphalt pavements only reached 100°F (38°C) immediately after treatment.

Treatments were made during the spring, when moisture was abundant and the fire hazard low. Ignition of combustible materials on the shoulder was infrequent except where dense dried vegetation occurred. Clean shoulders presented virtually no fire hazard, although dried, fine materials did produce a few easily extinguished fires (e.g., dried grasses and pine needles from nearby trees). In dense or tall vegetated areas ignition occurred after the second or third treatment due to the increase of dried debris. On occasion, the denser vegetation adjacent to the treated area would also ignite. The fires were minor and often went out on their own. Fires that persisted were immediately extinguished using water from a fire-control unit onboard a support truck. There was one incident where a fire spread beyond the right-of way when fire control equipment malfunctioned. Mowing prior to treatment helped to reduce ignition, especially where vegetation was tall and dense. When conditions warranted, the treated sites were monitored after treatment for possible fire restarts; however, none were observed.

The infrared equipment produced little smoke. Ignition of vegetation, however, did produce smoke and was most noticeable where significant amounts of desiccated material remained from earlier treatments.

4.1.4 Infrared Treatment Schedule

Table 4.1 shows the dates infrared treatments were applied. Some plots were treated eight times in 1997 and then reduced to four or six treatments in 1998 and 1999 (indicated in the table as I-8/4 and I-8/6). After the first year of treatment, there was no vegetation found on 6/21/97 at the infrared-treated plots; thus continuing with eight treatments per year appeared to be unnecessary. Subsequently these plots were reduced to four and six treatments to provide a better understanding of the effects of these lower treatment frequencies.

Table 4.1: Infrared Treatment Schedule

Year →		1996		1997						1998								1999								
Site 1 (Provolt)																										
Site (Plot)	Treat-ment Type	11/8/96	11/15/96	3/9/97	3/22/97	4/5/97	4/19/97	5/3/97	5/31/97	3/11/98	3/19/98	4/1/98	4/14/98	4/29/98	5/12/98	5/22/98	6/2/98		4/20/99	4/27/99	5/14/99	5/24/99		6/11/99	6/22/99	
1 (1B)	I-4	x		x		x			x	x	x		x			x					x	x		x	x	
1 (1E)	I-6	x	x	x		x	x		x	x		x	x		x	x	x		x	x	x	x		x	x	
1 (1H)	I-8/6	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x		x	x	
1 (2H)	I-8/4	x	x	x	x	x	x	x	x	x	x	x	x	x		x					x	x		x	x	
1 (2E)	I-4	x		x		x			x	x	x		x			x					x	x		x	x	
1 (2B)	I-6	x	x	x		x	x		x	x	x	x		x	x		x		x	x	x	x		x	x	
1 (3B)	I-8/4	x	x	x	x	x	x	x	x	x	x	x	x	x		x					x	x		x	x	
1 (3H)	I-6	x	x	x		x	x		x	x	x	x		x	x		x				x	x		x		
1 (3E)	I-4	x		x		x			x	x	x		x			x					x	x		x	x	
1 (5B)	I-8/6	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x		x	x	
1 (5E)	I-6	x	x	x		x	x		x	x		x	x		x	x	x		x	x	x	x		x	x	
1 (5H)	I-4	x		x		x			x	x	x		x			x					x	x		x	x	
Site 2 (Creswell)																										
Site (Plot)	Treat-ment Type											3/30/98	4/15/98	4/27/98	5/13/98	5/20/98	6/3/98		4/21/99	4/30/99	5/13/99	5/27/99		6/10/99	6/23/99	
2 (D)	I-4											x		x		x	x				x	x		x	x	
2 (E)	I-6											x	x	x	x	x	x		x	x	x	x		x	x	
2 (H)	I-4											x	x		x		x				x	x		x	x	
2 (I)	I-6											x	x	x	x	x	x		x	x	x	x		x	x	
Site 3 (Blachly)																										
Site (Plot)	Treat-ment Type									3/9/98	3/20/98	3/30/98	4/15/98	4/27/98	5/13/98	5/20/98	6/3/98	4/14/99	4/21/99	4/30/99	5/12/99	5/27/99	6/2/99	6/10/99	6/24/99	6/30/99
3 (B)	I-8									x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
3 (C)	I-6									x	x	x		x		x	x	a	a	x		x	x		x	x
3 (E)	I-4									x		x			x		x				x	x		x	x	
3 (I)	I-6									x		x		x	x	x	x			x	x	x		x	x	x
3 (J)	I-4									x		x			x		x				x	x		x	x	

a = For plot 3(C), the right shoulder was treated on 4/14/99 and the left shoulder was postponed until 4/21/99 due to fire hazards.

The treatment schedule was designed to:

1. Eliminate emerging seedlings when they appeared in the spring; and
2. Stress established plants with repeated treatments during the spring at intervals that would force plants to fully consume their root storage. The depleted root reserves would reduce the plants' ability to survive the summer heat and drought conditions.

4.2 HERBICIDE SECTIONS

4.2.1 Herbicide Applications

Herbicide treatments were applied according to the ODOT Integrated Vegetation Management (IVM) Plan. Generally they were applied in the spring at 4 - 8 ft (1.2 - 2.4 m) widths. Herbicides were not sprayed within 20 ft (6 m) of water unless approved for such use. Table 4.2 shows the types and quantities of herbicides used in this study.

4.2.2 Herbicide Spray Equipment

Three different maintenance crews were involved in this study and each applied the herbicides with the equipment available to them at the time.

Table 4.2 shows the types of equipment used in this study. The equipment is described below:

- Boom – Meters pesticide solution out of several nozzles along a pipe or other structure called a boom. Each nozzle along the boom delivers the same amount of pesticide to the application site.

- Boomless spray head – A single or multiple-tip cluster designed to produce a swath-like pattern. The swath is similar to that laid down by a boom sprayer. Boomless spray heads refer to all of the remaining equipment types:

    - Directa – A boomless sprayer with a multi-tip cluster.

    - Injector – A system that mixes water and chemical at the spray nozzle, eliminating tank mixing. Cluster nozzles deliver the pattern.

    - Norstar – A brand name of injector systems.

    - Radiarc – A vibrating head using straight stream nozzles. Vibration creates the pattern.

    - Single Fan nozzle – An off-center nozzle designed to spray a specific pattern width. Each nozzle sprays the entire distance of the pattern, unlike cluster nozzles that require several straight stream nozzles to spray a given distance.

4.2.3 Herbicide Schedule and Application Rates

Table 4.2 shows the herbicides applied in the test plots since 1994. The information comes from the individual Daily Spray Reports prepared by the spray applicator.

Table 4.2: Herbicide Treatment Schedule and Application Rates

Site	Date	Highway and milepoint	Spray Width	Herbicide & EPA Registration no.	Application Rate	Equipment Type
Site 1 (Provolt)	4/4/94	#272, MP 1-13.8	6-8’	Krovar (352-505) Amizol (264-119-AA)	5 lbs/acre 3 lbs/acre	Injector
	4/6/95	#272, MP 1-13.6 EB	6’	Krovar (352-505) Oust (352-401)	5 lbs/acre 4 oz/acre	Single Fan Nozzle
	4/24/95	#272, MP 13.6-1 WB	6’	Diuron (34704-648) Roundup (524-445)	8 lbs/acre 1.5 qts/acre	Single Fan Nozzle
	5/3/96	Water Gap, MP 0-1.25	8’ or less	Roundup Pro (524-475) Diuron (34704-648)	3 qts/acre 6 lbs/acre	Directa
	5/3/96	#272, MP 1.75-15.0 EB #272, MP 11.75-1.75 WB	8’ or less	Roundup Pro (524-475) Diuron (34704-648)	3 qts/acre 6 lbs/acre	Directa
	5/2/96	#272, MP 15.0-11.75 WB	4’ or less	Roundup Pro (524-475) Diuron (34704-648)	3 qts/acre 6 lbs/acre	Directa
	3/28/97	#272, MP 17.0-6.98 WB #272, MP 6.98-33.0 EB	8’	Krovar (352-505) Oust (352-401)	6 lbs/acre 2 oz/acre	Directa
	3/3/98	#272, MP 9-2 WB	4-6’	Diuron (34704-648) Roundup (524-475) Oust (352-401)	10 lbs/acre 1.5 qts/acre 3 oz/acre	Directa
	3/30/98	#272, MP 6-14	4-6’	Diuron (34704-648) Roundup Pro (524-475) Oust (352-401)	10 lbs/acre 1.5 qts/acre 3 oz/acre	Boom
	4/8/98	#272	2-8’ spot	Garlon (464-554)	34 oz/acre	Boom
	4/9/99	#272, MP 14-1	8’	Oust (352-401) Touchdown (10182-429), Direx 4L (1812-257)	3.5 oz/acre 2.5 qts/acre 8 qts/acre	Boom
Site 2 (Creswell)	4/26/95	#226, MP 0-16	Selective	Oust (352-401) Roundup (524-445)	4 oz/acre 48 oz/acre	Radiarc
	4/25/95	#226, MP 16-20	Selective	Oust (352-401) Roundup (524-445)	4 oz/acre 48 oz/acre	Radiarc
	5/12/96	#226, MP6-20	6’	Oust (352-401) Roundup (524-445)	4 oz/acre 48 oz/acre	Norstar
	5/6/97	#226, MP 0-18	8’	Krovar (352-505) Oust (352-401) Roundup (524-475)	6 lbs/acre 3 oz/acre 48 oz/acre	Norstar
	6/1/98	#226, MP 0-20	6’	Direx 4L (1812-257) Oust (352-401) Roundup Pro (524-445) Rodeo (524-343)	154 oz/acre 4 oz/acre 48 oz/acre 48 oz/acre	Boomless spray head
	6/17/98	#226, MP 7-12	6’	Direx 4L (1812-257) Oust (352-401) Roundup (524-445) Rodeo (524-343)	1.2 gal/acre 4 oz/acre 48 oz/acre 48 oz/acre	Boomless spray head
	6/2/99	#226, MP 9.69-10.03	6’	Roundup Pro (524-445)	48 oz/acre	Boomless spray head

Table 4.2 (continued): Herbicide Treatment Schedule and Application Rates

Site 3 (Blachly)	3/6/95	#229, MP 18.6-39	Spot	Rodeo (524-343)	0.75-gal/acre	Boomless spray head
	4/25/95	#229, MP 18.3-51.6	8'	Roundup (524-445) Oust (352-401)	1.5-qt/acre 4-oz/acre	Boomless spray head
	5/6/95	#229, MP 28.5-50	Spot	Rodeo (524-346)	3-qt/100 gal	Boomless spray head
	5/10/96	#229, MP 29.5-36	Spot	Garlon 3A (62719-37)	2-qt/100 gal	Handgun
	1997	#229		No spray		
	6/17/98	#229, MP 28-32	6'	Direx (1812-257) Oust (352-401) Roundup (524-445) Rodeo (524-343)	1.2-gal/acre 4-oz/acre 48-oz/acre 48-oz/acre	Boomless spray head
	5/6/99	#229, MP 18-38	6'	Krovar (352-505) Oust (352-401) Roundup Pro (524-475) Rodeo (524-343)	100-lbs/acre 3-oz/acre 48-oz/acre 32-oz/acre	Boomless spray head

4.3 CONTROL SECTIONS

Control sections were left untreated except as needed to correct motorist sight problems. These areas were spot mowed as needed to ensure safe sight distance.

4.4 MOW SECTIONS

Sites 2 and 3 received routine annual mowing as shown in Table 4.3 below. Site 1 did not contain mow test plots.

Table 4.3: Mow Schedule

Site	Date	Comments
Site 1	none	No mow plots at this site.
Site 2 Creswell	9/97	Entire area mowed to ditch line
	3/5/98	All test plots mowed to 2-3" prior to infrared treatments
	7/30/99	Plot 2B mowed to 2-3"
Site 3 Blachly	8/22/96	Entire area mowed 6' from edge of pavement
	9/4/97	Entire area mowed 6' from edge of pavement
	3/5/98	All test plots mowed to 2-3" prior to infrared treatments
	6/21/99	Plot 3G mowed to 2-3"

5.0 EVALUATION METHODS

5.1 PLOTS AND SUB-PLOTS

Each plot consisted of an area 0.12 - 0.40 mi (0.19 to 0.64 km) in length along the road shoulder. The plot had reference points at fixed intervals along the shoulder. The intervals were 50, 70 or 100 ft (15.2, 21.3 or 30.5 m). A smaller interval was used as needed to increase the number of plots for statistical purposes. The reference points were used to locate sub-plots. The actual location of the sub-plot was determined by a random offset of 0, ±1 or ±2 ft (0, ±0.3 or ±0.6 m) from the reference point, longitudinally with the road. The offset varied with each evaluation. Table 3.2 shows the plot lengths and sub-plot spacing.

The random offset was used to reduce potential for biased measurements. It avoided the need to place the measuring frame in the exact same location for each evaluation. Using a random offset did not allow a single sub-plot to be compared on a linear basis – that is, from one evaluation date to the next. Therefore, the plot as a whole was the smallest element that could be statistically compared.

5.2 MEASUREMENTS

At each subplot, a measuring frame was positioned at the appropriate offset, as shown in Figure 5.1. The frame was positioned so the 0-cm marking of the tape was at the edge of the pavement, perpendicular to the road.

All live vegetation that came in contact with one edge of the measuring frame between 15 and 60 cm was observed. The length of ground coverage was recorded and categorized as grass, broadleaf, or sedge. In addition, any vegetation that extended over the top of the measuring frame was measured by projecting downward over the tape. Dead vegetation was not counted.

In the case of sparsely spaced vegetation, the individual length of plant type coverage (grass, broadleaf or sedge) was recorded over the measured area, and then summed to equal the total length of growth per plant type in the 45-cm range. For example, if two species of grass were scattered along the 45-cm measuring area, the evaluation would proceed as follows:

- species 1 grass coverage: 2.2 cm, 1.8 cm, and 3.7 cm
- species 2 grass coverage: 2.5 cm and 3.6 cm.
- reported coverage = 2.2 + 1.8 + 3.7 + 2.5 + 3.6=13.8 cm length of grass vegetative cover.

Figure 5.1: Measuring frame used in evaluation

The height of vegetation was recorded next. In most cases, plant types within a treated area had somewhat uniform height, which made collecting the height data relatively easy. However, in the case of sparsely spaced vegetation, the heights of individual plants in contact with the measuring frame were noted, and an average height was computed and recorded. For example, if three broadleaf plants measured 7.3 cm, 11.9 cm, and 9.8 cm, the average height of broadleaf coverage would be reported at 9.6 cm.

Each observed plant type was then documented by its life cycle, as either annual or perennial.

Noxious weed counts were made over the first 100-foot interval (30.48 meters) and at the middle intervals of each plot. The investigator observed the vegetation along the roadside from the edge of the road to 60 cm from the road. All noxious weeds were identified and counted in order to estimate the total noxious weeds present along the roadside.

Any damage to the treated sites (such as a driveway turnout, unscheduled mowing or spraying, or any other type of damage to the site) was also recorded in the evaluation.

Appendix D contains instructions for the evaluator and photographic examples of measurements.

5.3 EVALUATION FORM

Evaluation forms were provided to record the specific vegetation characteristics at each sub-plot. This included the vegetation type (broadleaf, grass and sedge), life cycle (annual or perennial), coverage (centimeters) and height (centimeters). Comments were also made as needed to clarify a sub-plot characteristic or to record the presence of noxious weeds. Figure 5.2 shows an example of an evaluation form.

Site: **Grants Pass** Hwy: **238** Date: Evaluator:

Offset (feet)	Plot: MP + ft Treatment	Cover (cm)			Ave Height (cm)			A	P	Comments
		B.Leaf	Grass	Sedge	B.Leaf	Grass	Sedge			
-1	7 + 100 N 1C Herbicide									
-1	7 + 300 N 1C Herbicide									
1	7 + 400 N 1C Herbicide									
2	7 + 500 N 1C Herbicide									
-1	7 + 600 N 1C Herbicide									
0	7 + 700 N 1C Herbicide									
1	7 + 800 N 1C Herbicide									driveway
0	7 + 1000 N 1C Herbicide									
2	7 + 1100 N 1C Herbicide									turn around
2	7 + 1200 N 1C Herbicide									
-2	7.25 + 100 N 1B Infrared- 4									
0	7.25 + 200 N 1B Infrared- 4									

EXAMPLE

Figure 5.2: Sample Evaluation Form

5.4 EVALUATION SCHEDULE

Early in the project (March 1997) evaluations were conducted monthly at the infrared plots to gain knowledge of the treatment methods. In October 1997, the schedule was reduced to twice a year – once in June/July and once in October/November. Table 5.1 shows the dates of each evaluation in this study. The purpose for evaluating at these two periods is described below:

- June/July Evaluation – In the spring vegetation goes through a vigorous growth period, including seed production, growth and strengthening of its root system for the summer. To prevent this, the vegetation is treated during this period. By early summer, the vegetation is expected to be sparse and weakened. If properly treated, the vegetation should not survive the dry summer months. The June/July evaluation records the impact of the spring treatments and condition of the vegetation as summer began.

- October/November Evaluation – Treatments are generally not made during the summer. For infrared, fire hazards become a high risk. For herbicides the vegetation is less likely to absorb the chemical during dry weather, or rain may be required to activate the chemical process. In September, the precipitation returns, rejuvenating the surviving vegetation and promoting germination of the seedlings. Cooler temperatures that follow cause the growth rate to slow or become dormant. The fall evaluation records the long-term effectiveness of the spring treatment. If effective, the vegetation will be sparse and remain so through the winter months. If the treatment is ineffective, the vegetation will be flourishing, and an early fall treatment will be needed to control the vegetation.

Table 5.1: Evaluation Schedule

Site 1 (Provolt)	Site 2 (Creswell)	Site 3 (Blachly)
3/8/97		
4/12/97 *		
5/10/97 *		
5/25/97 *		
6/21/97		
10/25/97		
	4/27/98	4/27/98
7/22/98	7/13/98	6/30/98
11/10/98	11/3/98	10/27/98
7/14/99	7/20/99	7/20/99
11/8/99	11/2/99	10/12/99

* Only infrared plots were evaluated. Herbicide, mow and control plots were not evaluated.

6.0 UNPLANNED EVENTS

Prior to and during the study, several events occurred that may have affected the results of vegetation growth. These are listed by site in chronological order.

6.1 SITE 1 EVENTS

October 1998 – A maintenance crew inadvertently performed a shoulder blading operation along most of the shoulder at Site 1. The crews placed new aggregate in the drop-off and re-leveled the shoulder by scraping existing shoulder rock. The operation removed or dislodged nearly all the vegetation in the evaluation area (15 to 60 cm from edge of shoulder). The effect of the operation is quite obvious from the data, which shows a near absence of vegetation following the operation.

Summer 1999 – To correct a visual sight problem, tall growing berry vines rooted outside the evaluation area (15 to 60 cm) were removed. The growth was about 5 ft (1.5 m) high and leaned across the plot and close to the shoulder of the road. This created a sight problem in the curve areas. The crews used a mower deck that reached over the test plot without disturbance to the plot.

6.2 SITE 2 EVENTS

November 18, 1997 – Prior to the treatment and evaluation period, road shoulders were bladed as a part of the regularly scheduled maintenance work.

June 1998 – The mowing and control plots between MP 7.98 and 8.71 were accidentally treated with herbicides on the west-side shoulder only.

January 11, 1999 - To correct a hazardous shoulder drop-off problem, maintenance crews repaired small areas of shoulders near some road accesses. These areas had been damaged by vehicles making sharp turning movements. Because of the high use, vegetation seldom grew. Since the area affected was small in comparison to all the sub-plots, the sub-plots in these locations were removed from the study. The southbound areas were MP 8.546 - 8.594, MP 8.835 - 8.864, MP 9.228 - 9.345 and MP 9.908 - 9.943. Northbound areas were MP 10.034 - 9.983, MP 9.89 - 9.82, MP 9.682 - 9.675 and MP 9.339 - 9.294.

6.3 SITE 3 EVENTS

February 1996 – This area received heavy flooding from MP 28.1 – 28.6 prior to the test. Shoulder damage occurred from MP 28.1 - 28.4. The shoulders were rebuilt following the flood.

1998-1999 – The area from MP 28.1 – 28.4 typically floods over the shoulders and onto the road one or two times per year. Although not documented, some flooding did occur during this study.

April 14, 1999 – About 0.34 miles (547m) of road shoulder at plot 3C was being treated with infrared when a fire spread beyond the right-of-way and up a hillside. The fire was quickly extinguished. This event occurred following several weeks of dry weather. Further infrared treatments were suspended for the day due to the hazard.

June 1999 – To correct a visual sight problem, tall growing grass located outside the evaluation area (15 to 60 cm) was mowed. The grass was 3 - 5 ft (1 - 1.5 m) high and leaned across the plot and close to the shoulder of the road. This created a sight problem in the curve areas. To correct the problem, the crews used a mower deck that reached over the test plot without disturbance to the plots. The mowing occurred at MP 28.66 to 28.56.

6.4 EVENTS AT ALL SITES

Several plots were located near private properties that contained landscaping or crops. These areas frequently received unsolicited treatments, including mowing or herbicide spraying. The evaluator took note of the areas that appeared to have been affected.

7.0 ANALYSIS

7.1 CLIMATOLOGICAL DATA

A review of the climatological data was made for documentation purposes and to determine if weather conditions deviated significantly from normal weather patterns. In particular, it was of interest to know if the conditions could affect plant growth, moisture content or the effectiveness of the vegetation treatments during the study.

7.1.1 Historical Data

Climatic sensors were not installed at the test sites, but records were available from nearby NOAA/NWS weather stations. The locations are shown below in Table 7.1.

Table 7.1: Historical summary of nearby NOAA/NWS weather stations

	Station Name (ID No)	Approximate Location	Lat-itude	Long-itude	Elev-ation	Daily Max Temp	Daily Min Temp	Ave. Annual Precip	Period of Record for Temp & Precip
Site 1	Applegate (350217)	Jackson County, Hwy #272 MP 18.17, 6 mi. east of site 1	42° 15'N	123° 10'W	1280 ft	NA	NA	25.39	1/1/79 to 12/31/98
	Ruch (357391)	Jackson County, Hwy #272 MP 25.62, 14 mi. east of site 1	42° 14'N	123° 2'W	1550 ft	68.4	38.7	25.94	4/1/63 to 12/31/98
	Williams 1 N (359390)	Jackson County, 6 mi. south of site 1	42° 14'N	123° 16'W	1350 ft	58.8 [1]	36.9 [1]	34.28	8/1/48 to 12/31/98
Site 2	Cottage Grove 1 S (351897)	Lane County, 4 mi. south of site 2	43° 47'N	123° 4'W	650 ft	64.0	39.9	46.54	7/1/48 to 12/31/98
	Eugene WSO Airport (352709)	Lane County, 20 mi. north of site 2	44° 7'N	123° 13'W	359 ft	63.3	41.8	46.71	12/1/39 to 12/31/98
Site 3	Alsea Fish Hatchery (350145)	Lincoln County, Hwy #27 MP ~26 18 mi N of site 3	44° 24'N	123° 45'W	230 ft	NA	NA	92.64	10/14/54 to 12/31/98
	Corvallis Water Bureau (351877)	Benton County, 21 mi. N of site 3	44° 31'N	123° 27'W	592 ft	61.3	40.7	68.28	7/1/48 to 12/31/98
	Fern Ridge (352867)	Lane County, 17 mi. SE of site 3	44° 7'N	123° 18'W	380 ft	62.4	42.0	40.61	7/16/43 to 12/31/98
	Noti 1 NW (356173)	Lane County, Hwy #62, MP ~42, 10 mi. SE of site 3	44° 4'N	123° 28'W	450 ft	63.8	40.1	61.30	4/1/64 to 4/30/91

[1] Unofficial values. Computed from available daily data during 1961 to 1990.

The data were broken down into three time periods: March through May; June through September; and October through February.

March through May was typically when the infrared and herbicide treatments were applied. For infrared treatments, higher moisture content in or on the vegetation increases the amount of mass that needs to be heated, and may require a longer exposure to reach effective temperatures. However, some moisture could have a beneficial impact by reducing the potential of fire and providing mass to retain and transfer heat to the plant. The effect moisture had on the infrared treatment was not studied, but it was assumed that longer exposure times were needed in the high moisture vegetation areas.

For herbicides, rainfall can have a beneficial or detrimental effect depending on the herbicide. In general, normal rainfall should have little impact on the effectiveness of the herbicide, providing it is applied according to the label. For some residual herbicides, a rainfall after the application is essential to help activate the chemical process. For others, best results are obtained when the plant is actively growing, which could be aided by rainfall. One exception might be an intense rainfall that could prematurely wash a residual chemical out of the soil.

By June, the treatments had typically been completed. If successful, they stunted or eradicated the vegetation and kept it from going to seed. If the treatments were not sufficient, the surviving vegetation and seeds could propagate. Above normal precipitation could revive the vegetation and cause it to spread.

From October through February, vegetation becomes dormant and the growth rate slows or stops. Precipitation levels during this time have less impact on the growth of the vegetation unless extreme conditions occur. Flooding could wash out the vegetation or transport new seeds into the shoulder area. A drought could weaken the plant root system.

During the course of this study, 1996 to 1999, it was found that precipitation from March through May was just above normal (Table 7.2 and Figure 7.1). The historical average precipitation for the eight stations was 10.72 in. (272 mm). For this study, the wettest period occurred in 1998 at 2.1 in. (53 mm) above normal (historical average); and the driest period occurred in 1999 at just 0.2 in. (5 mm) below normal. Of the three sites, Site 3 had the most precipitation, but was only a couple inches above normal. For all sites, the data showed that precipitation was 10% to 20% above normal in 1996, 1997 and 1998. This could suggest the moisture content and growth rate was higher than normal. The increased moisture would require longer infrared exposure to effectively control the vegetation.

Table 7.2: Precipitation (in inches) for March through May of nearby NOAA/NWS weather stations

Site	March-May (3 months)	1996	1997	1998	1999	Historical Average	Std Dev
1	Applegate	7.14	6.51	10.75	3.42	6.06	2.50
	Ruch	7.73	3.53	5.62	N/a	5.67	2.35
	Williams	10.04	7.45	11.30	3.66	6.65	3.16
2	Cottage Grove	7.68 *	n/a	n/a	9.90	11.61	3.39
	Eugene WSO	9.86	12.97	12.72	8.64	10.46	4.02
3	Alsea Fish Hatchery	22.82	25.14	20.40	21.71	21.89	5.49
	Corvallis Water Bureau	16.94	18.17	16.37	14.88	14.76	4.51
	Fern Ridge	11.88 *	12.60 *	12.82 *	11.42 *	8.66	2.86
	Average (8 stations)	**11.76**	**12.34**	**12.85**	**10.52**	**10.72**	
	% of historical average	**110 %**	**115 %**	**120 %**	**98 %**		

*5 or more days of data is missing and actual precipitation could be higher than shown.

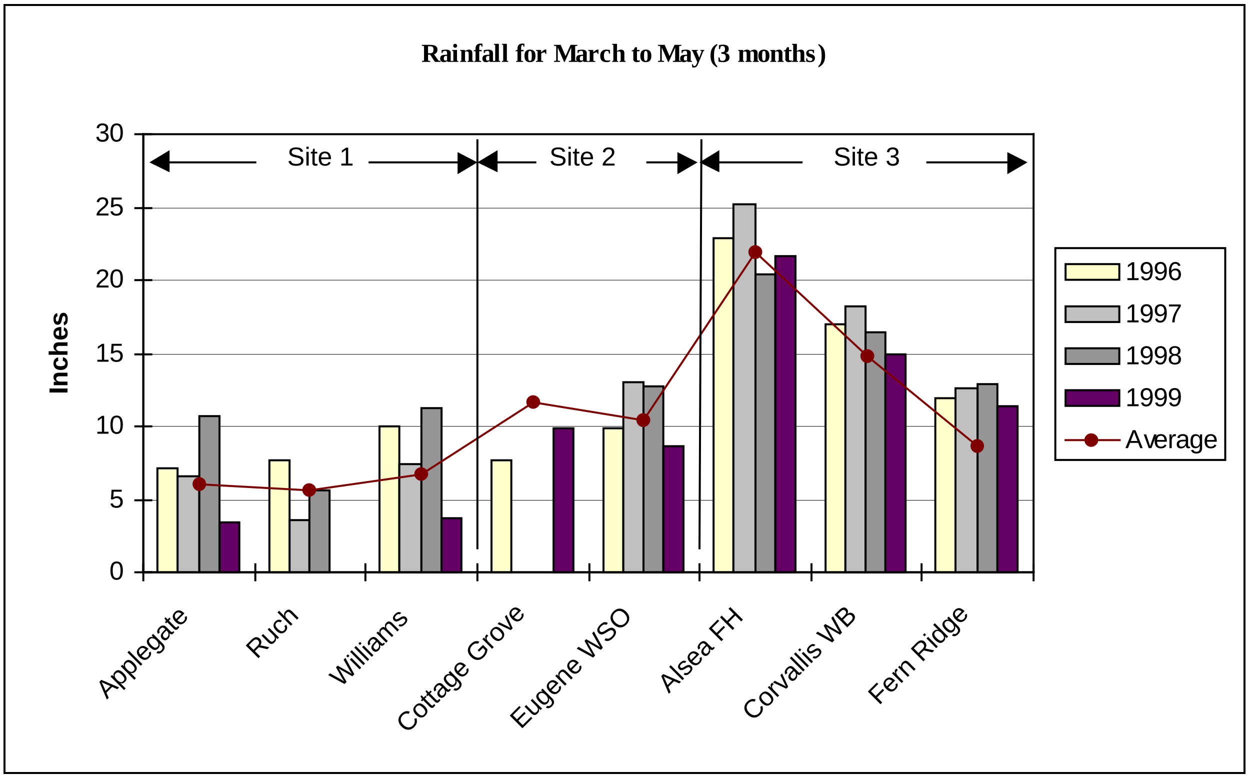


Figure 7.1: Precipitation for March through May

Precipitation during the summer months of June through September is shown in Table 7.3 and Figure 7.2. The years 1996, 1998 and 1999 were typically 1.0 - 2.5 in. (25 - 63 mm) below normal, or 0.7 to 1.5 standard deviations. In 1997 rainfall at Site 1 (Applegate and Williams) was about 0.7 - 0.8 in. (18 - 20 mm) above normal (0.5 to 0.9 standard deviations). At Site 2 (Eugene WSO) rainfall was 2.7 in. (70 mm) above normal (1.4 standard deviations). At Site 3 (Alsea, Corvallis, Fern Ridge), rainfall was 4 - 6 in. (100 - 150 mm) above normal (2 to 3 standard deviations). The data suggests the precipitation could have been favorable to vegetation growth in 1997, and detrimental in 1996 and 1998.

Table 7.3: Precipitation (in inches) for June through September of nearby NOAA/NWS weather stations

Site	June-Sept (4 months)	1996	1997	1998	1999	Historical Average	Standard Deviation
1	Applegate	1.11	2.97	1.00	1.66	2.18	0.99
	Ruch	1.19	2.61	0.18	n/a	2.67	1.53
	Williams	1.17	2.82	0.33	2.02	2.14	1.34
2	Cottage Grove	n/a	n/a	n/a	3.22	4.26	1.54
	Eugene WSO	3.51	6.79	1.14	1.84	4.06	1.93
3	Alsea Fish Hatchery	6.12	13.05	4.41	3.31	7.12	2.98
	Corvallis Water Bureau	3.68	8.48	2.04	1.35	4.16	2.00
	Fern Ridge	3.2	8.47	2.06	2.37*	3.44	1.66
	Average (8 stations)	**2.85**	**6.46**	**1.59**	**2.23**	**3.75**	
	% of historical average	**76 %**	**172 %**	**42 %**	**59 %**		

* 5 or more days of data is missing and actual precipitation could be higher than shown.

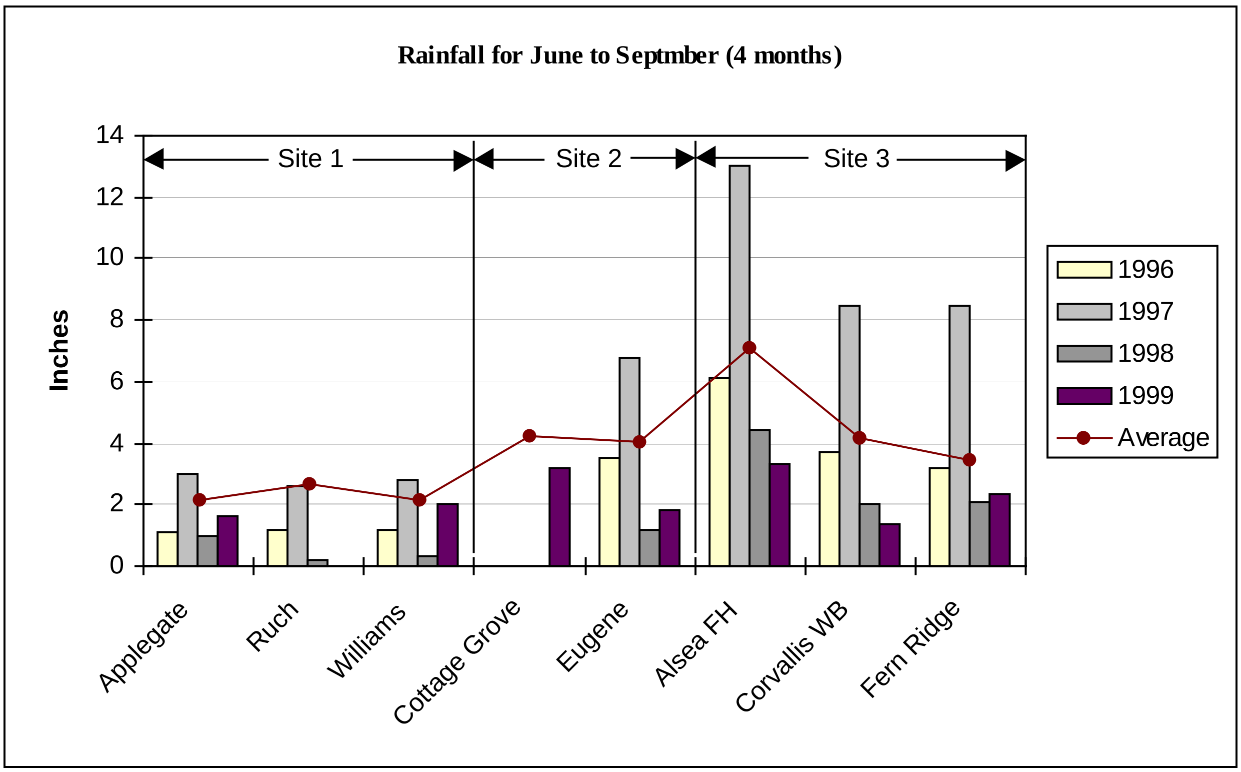


Figure 7.2: Precipitation for June through September

The total precipitation for the rainy months of October through February is shown in Table 7.4 and Figure 7.3. The table shows that 1996, 1997 and 1999 were 42% - 64% above the historical average in precipitation, whereas 1998 was only 6% above normal, or close to a normal winter for precipitation.

The precipitation in 1996, 1997 and 1999 was 3 - 36 in. (75 - 900 mm) above normal (0.5 to 2.8 standard deviations). In 1998, two sites (Ruch and Eugene) were below normal by 2 and 7 in. (55 - 180 mm) respectively (0.3 to 0.8 standard deviations). The other five sites were above normal by 0.5 to 7 in. (13 - 170 mm) (0.1 to 0.7 standard deviations).

Table 7.4: Precipitation (in inches) for October through February of nearby NOAA/NWS weather stations

Site	Oct-Feb (5 months)	1995-6	1996-7	1997-8	1998-9	Historical Average	Standard Deviation
	Applegate	23.66	32.46	25.52	30.39	19.52	8.17
1	Ruch	24.95	20.87	15.24		17.41	6.44
	Williams	29.95	43.35	28.46	37.54	25.19	9.22
	Cottage Grove	43.58			44.37	30.79	8.36
2	Eugene WSO	58.44	39.50	25.17	39.91	32.36	9.20
	Alsea Fish Hatchery	96.84	85.98	68.17	100.89	64.27	17.34
3	Corvallis Water Bureau	74.45	65.08	56.02	85.02	49.33	14.44
	Fern Ridge	41.16*	45.34*	29.32*	46.73*	28.80	7.69
	Average (8 stations)	**49.13**	**47.51**	**35.41**	**54.98**	**33.46**	
	% of historical average	**147 %**	**142 %**	**106 %**	**164 %**		

* 5 or more days of data is missing and actual precipitation could be higher than shown.

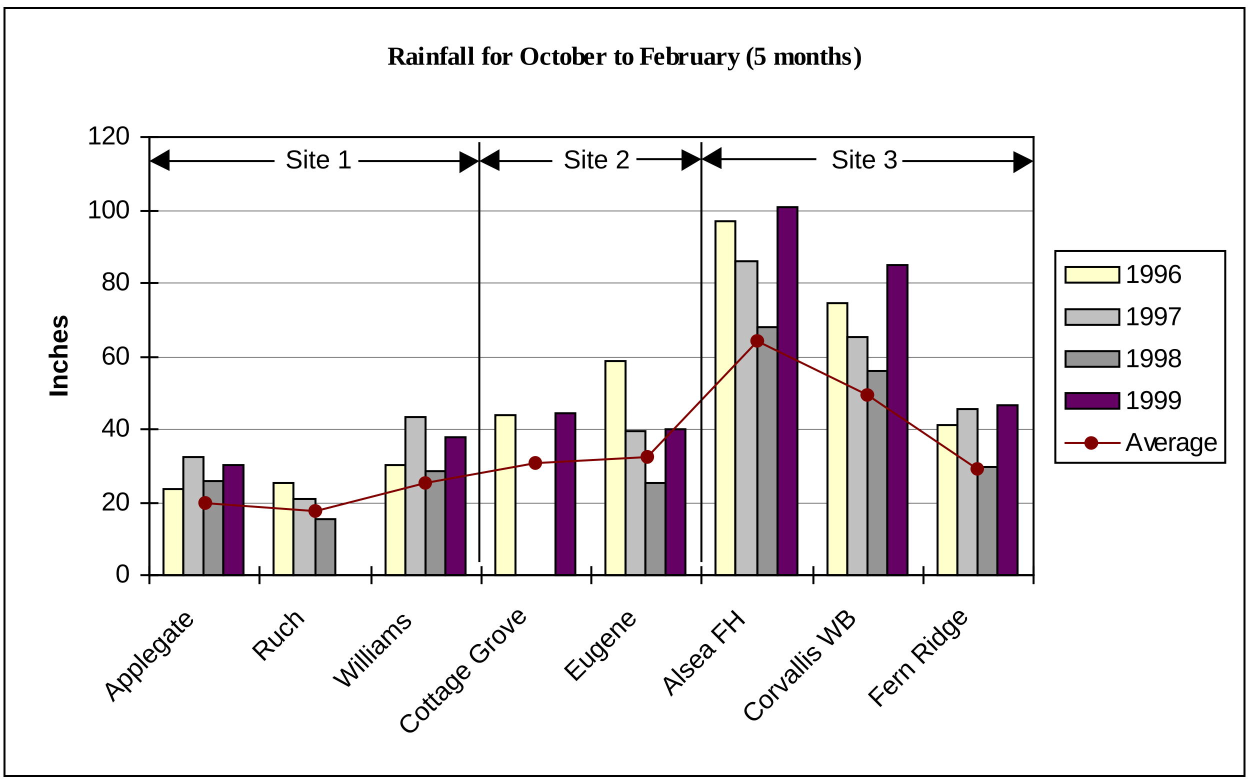


Figure 7.3: Precipitation for October through February

Although there was a significant increase in precipitation during this five-month period, it occurred during the dormant months and is not believed to have had a significant effect on the treatments or spring growth rates.

Table 7.5 summarizes the precipitation for all periods during the study. Overall, the precipitation was the highest in 1997 and could have provided favorable growing conditions. For 1996, the precipitation began high but dropped to below normal for the summer when the vegetation could benefit the most for surviving into the fall. Similarly, 1998 began high but also dropped below normal for the summer.

Table 7.5: Percent change of precipitation levels compared to historical values

Period	1996	1997	1998	1999
Oct-Feb	+47%	+42%	+6%	+64%
March-May	+10%	+15%	+20%	–2%
June-Sept	–24%	+72%	–58%	

7.2 TIMING OF EVALUATIONS TO TREATMENTS

As discussed in Section 5.4, field evaluations were conducted twice a year, in June/July and October/November. The June/July evaluations occurred two to 16 weeks after the treatments. This time period can have an impact on the condition of the vegetation when evaluated. Both infrared and herbicide treatments need time to affect the plant, whether they act on the foliage or root system. Sufficient time should also be allowed to give the vegetation time to recover from the treatment if possible. Excessive time, however, can lead to growth of new seedlings.

Table 7.6 below shows the interval of time from the last treatment to the evaluation. Nearly all evaluations occurred at least two weeks later, which was believed to be ample time for the treatments to take effect. Several evaluations, however, were over six weeks from the last treatment. At six weeks, a residual herbicide could still be effective; but the infrared may no longer have a controlling effect on new sprouts.

To test this hypothesis, the evaluations conducted six or more weeks following infrared treatments were examined. There were two occasions that met this criterion – a 7/22/98 evaluation at Site 1 and a 7/13/99 evaluation at Site 3. Contrary to expectations, however, these evaluations recorded little growth; vegetation coverage only averaged about 1%. This finding might be partially attributed to the low precipitation levels in 1998 (20% of normal, June to September) or possibly to the effectiveness of the treatment. The lack of data for evaluations conducted greater than six weeks following treatment prevents any definitive conclusions.

Table 7.6: Interval Between Treatments and Spring Evaluations

Location	Year	Treatment type	Date of Last Treatment	Date Evaluated	Time from last treatment days (weeks)
Site 1	1997	Infrared	11/15/96	3/8/97	113 (16)
		Herbicide	5/3/96		309 (44)
		Infrared	4/5/97	4/12/97	7 (1)
		Infrared	5/3/97	5/10/97	7 (1)
		Infrared	5/3/97	5/25/97	22 (3)
		Infrared	5/31/97	6/21/97	21 (3)
		Herbicide	3/28/97		43 (6)
	1998	Infrared	6/2/98	7/22/98	**50 (7)**
		Herbicide	4/8/98		105 (15)
	1999	Infrared	6/30/99	7/14/99	14 (2)
		Herbicide	4/9/99		96 (14)
Site 2	1998	Infrared	6/2/98	6/30/98	28 (4)
		Herbicide	6/17/98		13 (2)
	1999	Infrared	6/30/99	7/20/99	20 (3)
		Herbicide	6/2/99		48 (7)
Site 3	1998	Infrared	6/2/98	7/13/98	**41 (6)**
		Herbicide	6/17/98		26 (4)
	1999	Infrared	6/30/99	7/20/99	20 (3)
		Herbicide	5/6/99		75 (11)

7.3 VEGETATION GROWTH DATA

The data in this study were collected using the methods described in Section 5. Some data points were not used in the analysis. This includes sub-plots that were located at road approaches, driveways or vehicle pull-outs and those damaged by shoulder repair. Sub-plots 4A-4H at Site 1 were dropped from the study after 1996, and the research funds were used to support treatments at Sites 2 and 3. The dropped sub-plots were not used in the analysis.

All vegetation was identified by type (broadleaf, grass or sedge) and life cycle (annual or perennial). In general, perennial grass was the most common vegetation and sedge was not found at any sub-plot. An exception was Site 1, where annuals were more common than perennials.

ODOT has a general policy on vegetation control activities. It prescribes 5 levels of service (LOS) for 4 different road categories. The LOS ranges from “A” to “E”. For this study the sites would comply with either LOS “B” or “C” conditions. LOS “B” allows no vegetation 4 ft (2.5 m) from the edge of the pavement, whereas, LOS “C” allows vegetation, providing it is less than 6 in. (15 cm) high within four feet from the edge of the pavement and it does not impede sight distance. The general policy and LOS is included in Appendix I.

7.3.1 Site 1 (Provolt)

Table 7.7 summarizes the data for the field evaluations of vegetation growth at Site 1. Prior to this research study, test plots at Site 1 had been treated annually with herbicides. The last herbicide treatment had occurred on 5/3/96 with a mixture of Roundup (3 qt/acre) and Diuron (6 lbs/acre).

7.3.1.1 Infrared Plots

Infrared treatments commenced at 12 plots on 11/8/96 and continued to 6/30/99. Each plot received four, six or eight treatments per year as shown in Table 4.1. In the first season (1996/97), treatments were made both fall and spring months – 2 treatments in November 1996 and the remainder in March through May 1997. For 1998 and 1999, the schedule was changed to perform all treatments in the spring, generally early March through June. In addition, the plots receiving eight treatments in 1996/97 were reduced to four to six treatments for 1998 and 1999. This change was made because there was no vegetation found at any of the infrared plots on 6/21/97, and continuing with eight treatments appeared to be unnecessary. The change is shown in Table 4.1.

The first Site 1 infrared evaluation was conducted on 3/8/97, four months after the November treatments. It found vegetation covered 6.4% of the shoulder (5.7% grass species, 0.7% broadleaf species). Treatments resumed on 3/9/97, 3/22/97 (I-8 plots only) and 4/5/97. The next evaluation (4/12/97) showed that coverage had dropped to 1.3% (1.0% grass, 0.2% broadleaf). For the last spring treatment (6/21/97), there was no grass or broadleaf in the subplots (0% grass, 0% broadleaf). It should be noted that there was some vegetation in the treated area but none was found in the subplot. Rainfall during this period was normal. It was unknown if there were any residual effects from the past annual herbicide treatment (5/3/96), but none was suspected.

The plots were evaluated again on 10/25/97 after five months of growth. Prior to the evaluation, however, an unplanned shoulder blading operation eradicated most of the vegetation. Thus the evaluation showed that vegetation in the infrared plots only increased marginally to 0.4% coverage (0.4% grass, 0% broadleaf). After a second year of treatment and evaluation (11/10/98) the coverage was found to be 0.5% (0.5% grass, 0% broadleaf). By the end of the third year (11/8/99) the coverage had increased to 3.3% (1.4% grass, 1.8% broadleaf). Some of these variations could be from the random sampling of the plots.

7.3.1.2 Control Plots

The control plots began with coverage of 17.9% (16.2% grass, 1.6% broadleaf) on 3/8/97. The coverage had increased to 30.2% (16.8% grass, 13.4% broadleaf) in the first year (6/21/97). By the fall of the first year (10/25/97) it had decreased to 0.8% (0.8% grass, 0% broadleaf) as a result of the same unplanned shoulder blading discussed above.

In the second year (7/22/98) the vegetation coverage increased to 3.2% (0.3% grass, 2.9% broadleaf), and then it decreased to 0.4% (0.2% grass, 0.2% broadleaf) by the fall (11/10/98), perhaps as a result of the very low summer precipitation (only 20% of normal).

In the third year (7/14/99) the coverage increased to 10.0% (0% grass, 10.0% broadleaf), and then to 12.8% (4.8% grass, 8.0% broadleaf) at the last evaluation in the fall (11/8/99).

It is interesting to note that the broadleaf coverage was greater than grass at the end of the study, where the other sites displayed more grass. It may be that the shoulder blading operation provided a condition more favorable to broadleaf plants than grasses. Although some grass (less than 1%) appeared shortly after the blading, it did not begin to thrive until the last evaluation on 11/8/99, two years after the blading. In contrast, broadleaf coverage of 2.9% was seen one year after the blading and ranged from 8% to 10% after two years.

7.3.1.3 Herbicide Plots

The herbicide plots had greater vegetation coverage than the infrared plots at the start of the evaluation period (3/8/97), with 19.3% coverage (14.4% grass, 4.9% broadleaf). It should be noted, however, that the first 1997 evaluation of Site 1 reflects 44 weeks of growth from the previous herbicide application (Table 7.6). The plots were treated on 3/28/97 with Krovar (6 lbs/acre) and Oust (2 oz/acre). Evaluation of the plots on 6/21/97 showed that the vegetation coverage was reduced to 5.9% (5.2% grass, 0.8% broadleaf). The coverage remained between 0.3% to 1.2% for the next 2 years. On the last evaluation (11/8/99) the coverage had increased to 2.7% (1.2% grass, 1.5% broadleaf).

In summary, the average vegetation coverage among all infrared plots was 1.0%, ranging from 0% to 9.6% over the course of the study. The average coverage among all herbicide plots was 1.9%, ranging from 0.3% to 19.3% over the entire period. The infrared treatments appeared to produce better results than the herbicide treatments, leaving an average vegetation coverage of 1.3% with four treatments and 0.5% with six treatments. These findings cannot be regarded as conclusive, however, due to the impact of the shoulder blading operation in the study area.

At the conclusion of this test period (11/8/99), two years after the shoulder blading, the herbicide plots were found to have a coverage of 2.7% vegetation. The six-treatment infrared plots had a similar coverage of 2.4% vegetation. The four-treatment infrared plots showed slightly more coverage at 4.0%. The average of both four- and six-treatment plots was 3.3%.

For this test period, both the infrared and herbicide plots would comply with Level of Service (LOS) “B”, but in some cases approaching LOS “C”. These treatments would have been adequate for all two-lane highways.

Table 7.7: Summary of Field Evaluation Data at Site 1 (Provolt)

Treat-ment	Date	# of Sub-plots	Sub-plots w/veg	Pct w/veg	Pct Coverage by Type				Height (cm)		Life Cycle	
					BL*	GR*	S*	All	BL*	GR*	Annual	Perenn.
I-4	03/08/97	*(1997)*	19	37%	1.7%	6.6%	0.0%	8.3%	2.0	3.1	35%	6%
	04/12/97	52	0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	05/10/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	05/25/97		3	6%	0.6%	0.1%	0.0%	0.7%	6.0	9.0	0%	6%
	06/21/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	10/25/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	07/22/98	*(98-99)*	8	10%	0.3%	1.1%	0.0%	1.4%	5.0	10.8	0%	0%
	11/10/98	78	4	5%	0.0%	0.9%	0.0%	0.9%	0.0	10.5	0%	0%
	07/14/99		4	5%	1.1%	0.1%	0.0%	1.2%	22.1	0.0	0%	0%
	11/08/99		18	23%	2.5%	1.5%	0.0%	4.0%	5.9	6.7	0%	0%
	Average		5.7	**11%**	0.7%	0.6%	0.0%	**1.3%**	5.5	4.7	**0.0%**	**0.0%**
I-6	03/08/97	*(1997)*	17	34%	0.5%	9.1%	0.0%	9.6%	1.7	3.9	34%	0%
	04/12/97	50	7	14%	0.8%	3.1%	0.0%	3.9%	6.0	5.3	8%	8%
	05/10/97		11	22%	1.1%	5.7%	0.0%	6.8%	6.3	7.5	22%	0%
	05/25/97		4	8%	0.0%	1.9%	0.0%	1.9%	0.0	10.0	0%	8%
	06/21/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	10/25/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	07/22/98	*(98-99)*	4	5%	0.0%	0.5%	0.0%	0.5%	0.0	10.3	0%	0%
	11/10/98	75	0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	07/14/99		2	3%	0.2%	0.0%	0.0%	0.2%	25.0	0.0	0%	0%
	11/08/99		13	17%	1.1%	1.3%	0.0%	2.4%	4.9	5.5	0%	0%
	Average		3.2	**4%**	0.2%	0.3%	0.0%	**0.5%**	5.0	2.6	**0.0%**	**0.0%**
I-8	03/08/97	51	6	12%	0.0%	1.4%	0.0%	1.4%	0.0	2.4	12%	0%
	04/12/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	05/10/97		4	8%	0.0%	0.9%	0.0%	0.9%	0.0	3.5	8%	0%
	05/25/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	06/21/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	10/25/97		5	10%	0.0%	1.1%	0.0%	1.1%	0.0	5.4	0%	0%
	n/a		No data		Plots changed to I-4 or I-6							
	n/a		No data		Plots changed to I-4 or I-6							
	n/a		No data		Plots changed to I-4 or I-6							
	n/a		No data		Plots changed to I-4 or I-6							
	Average		1.8	**4%**	0.0%	0.6%	0.0%	**0.6%**	0.0	2.7	**0.0%**	**0.0%**

Table 7.7 (continued): Summary of Field Evaluation Data at Site 1 (Provolt)

Treat-ment	Date	# of Sub-plots	Sub-plots w/veg	Pct w/veg	Pct Coverage by Type				Height (cm)		Life Cycle	
					BL*	GR*	S*	All	BL*	GR*	Annual	Perenn.
I-all	03/08/97	153	42	27%	0.7%	5.7%	0.0%	6.4%	1.9	3.3	27%	2%
	04/12/97		7	5%	0.2%	1.0%	0.0%	1.3%	6.0	5.3	3%	3%
	05/10/97		15	10%	0.4%	2.1%	0.0%	2.5%	6.3	6.3	10%	0%
	05/25/97		7	5%	0.2%	0.7%	0.0%	0.9%	6.0	9.8	0%	5%
	06/21/97		0	0%	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0%	0%
	10/25/97		5	3%	0.0%	0.4%	0.0%	0.4%	0.0	5.4	0%	0%
	07/22/98		12	8%	0.1%	0.8%	0.0%	1.0%	5.0	10.6	0%	0%
	11/10/98		4	3%	0.0%	0.5%	0.0%	0.5%	0.0	10.5	0%	0%
	07/14/99		7	5%	0.7%	0.1%	0.0%	0.7%	22.9	0.0	0%	0%
	11/08/99		36	24%	1.8%	1.4%	0.0%	3.3%	5.6	6.1	0%	0%
	Average		10.7	**7%**	0.4%	0.5%	0.0%	**1.0%**	5.6	5.4	**0.0%**	**0.0%**
Herb	03/08/97	150	62	41%	4.9%	14.4%	0.0%	19.3%	2.3	4.6	41%	5%
	n/a				Not evaluated							
	n/a				Not evaluated							
	n/a				Not evaluated							
	06/21/97		15	10%	0.8%	5.2%	0.0%	5.9%	5.5	24.9	9%	3%
	10/25/97		3	2%	0.0%	1.0%	0.0%	1.0%	0.0	8.0	0%	0%
	07/22/98		4	3%	0.3%	0.1%	0.0%	0.4%	25.0	18.0	0%	0%
	11/10/98		1	1%	0.0%	0.3%	0.0%	0.3%	0.0	11.0	0%	0%
	07/14/99		7	5%	1.2%	0.0%	0.0%	1.2%	33.2	7.0	0%	0%
	11/08/99		18	12%	1.5%	1.2%	0.0%	2.7%	5.4	9.3	0%	0%
	Average		8.0	**5%**	0.6%	1.3%	0.0%	**1.9%**	11.5	13.0	**1.4%**	**0.6%**
Cntrl	03/08/97	101	40	40%	1.6%	16.2%	0.0%	17.9%	2.3	3.2	38%	4%
	n/a				Not evaluated							
	n/a				Not evaluated							
	n/a				Not evaluated							
	06/21/97		43	43%	13.4%	16.8%	0.0%	30.2%	0.0	0.0	35%	28%
	10/25/97		3	3%	0.0%	0.8%	0.0%	0.8%	0.0	8.0	0%	0%
	07/22/98		11	11%	2.9%	0.3%	0.0%	3.2%	32.8	10.0	0%	0%
	11/10/98		5	5%	0.2%	0.2%	0.0%	0.4%	5.5	6.7	0%	0%
	07/14/99		37	37%	10.0%	0.0%	0.0%	10.1%	25.8	21.0	0%	0%
	11/08/99		59	58%	8.0%	4.8%	0.0%	12.8%	8.8	5.4	0%	0%
	Average		26.3	**26%**	5.7%	3.8%	0.0%	**9.6%**	12.1	8.5	**5.8%**	**4.6%**

Note: Average is for the period of 6/21/97 to 11/8/99 only.
* BL = Broadleaf; G = Grass; S = Sedge

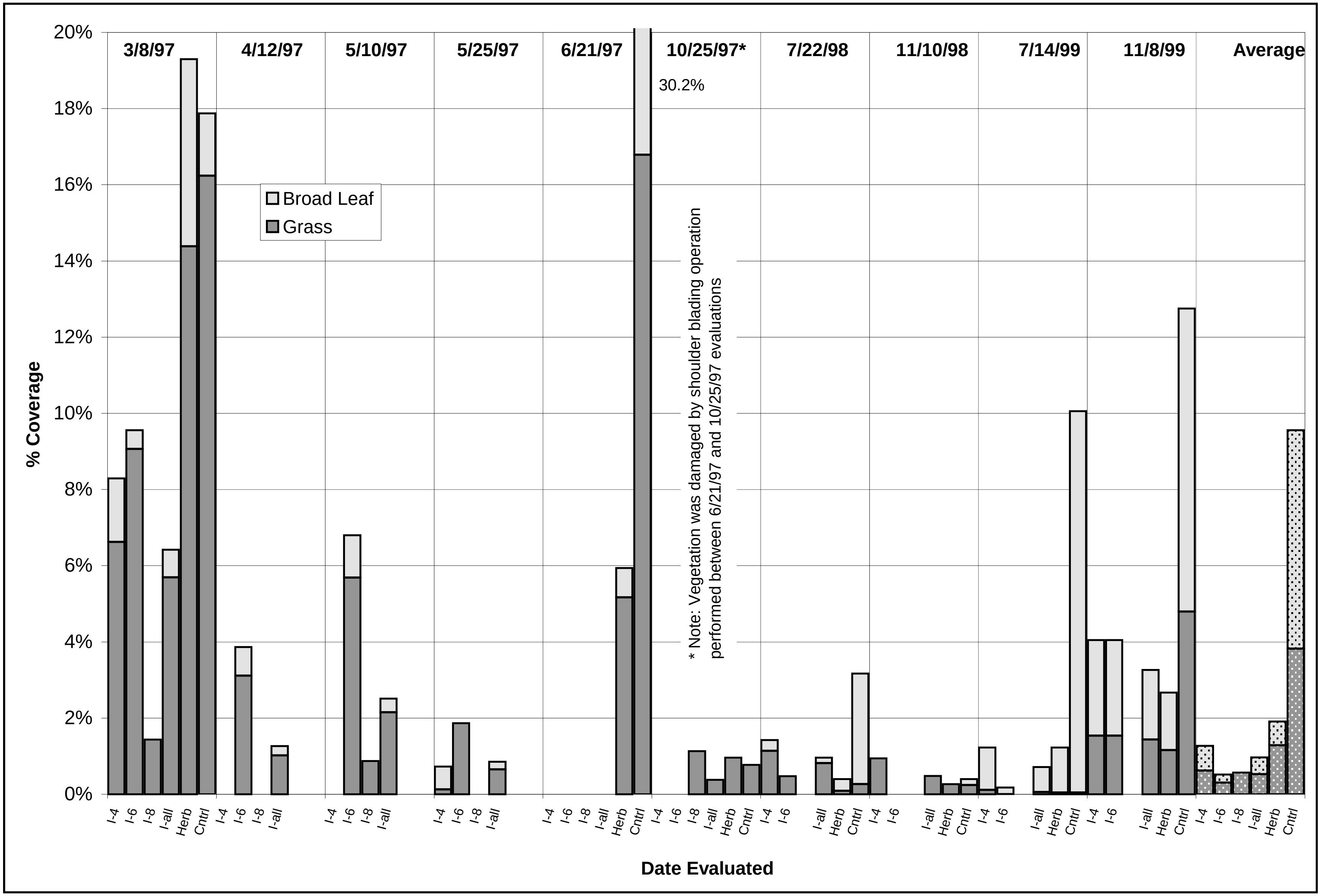


Figure 7.4: Site 1 - Percent vegetation coverage, grouped by date

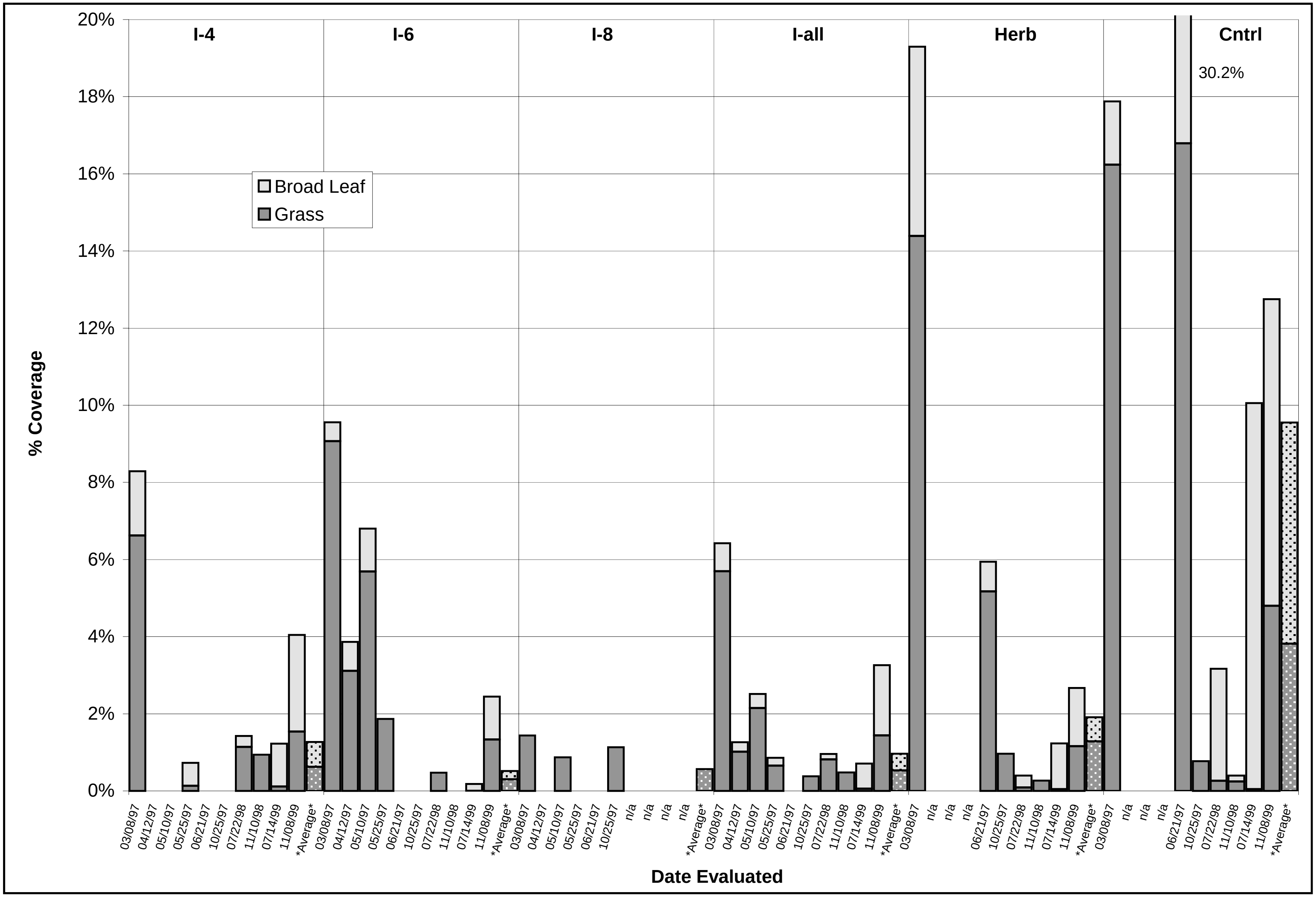


Figure 7.5: Site 1 - Percent vegetation coverage, grouped by treatment type

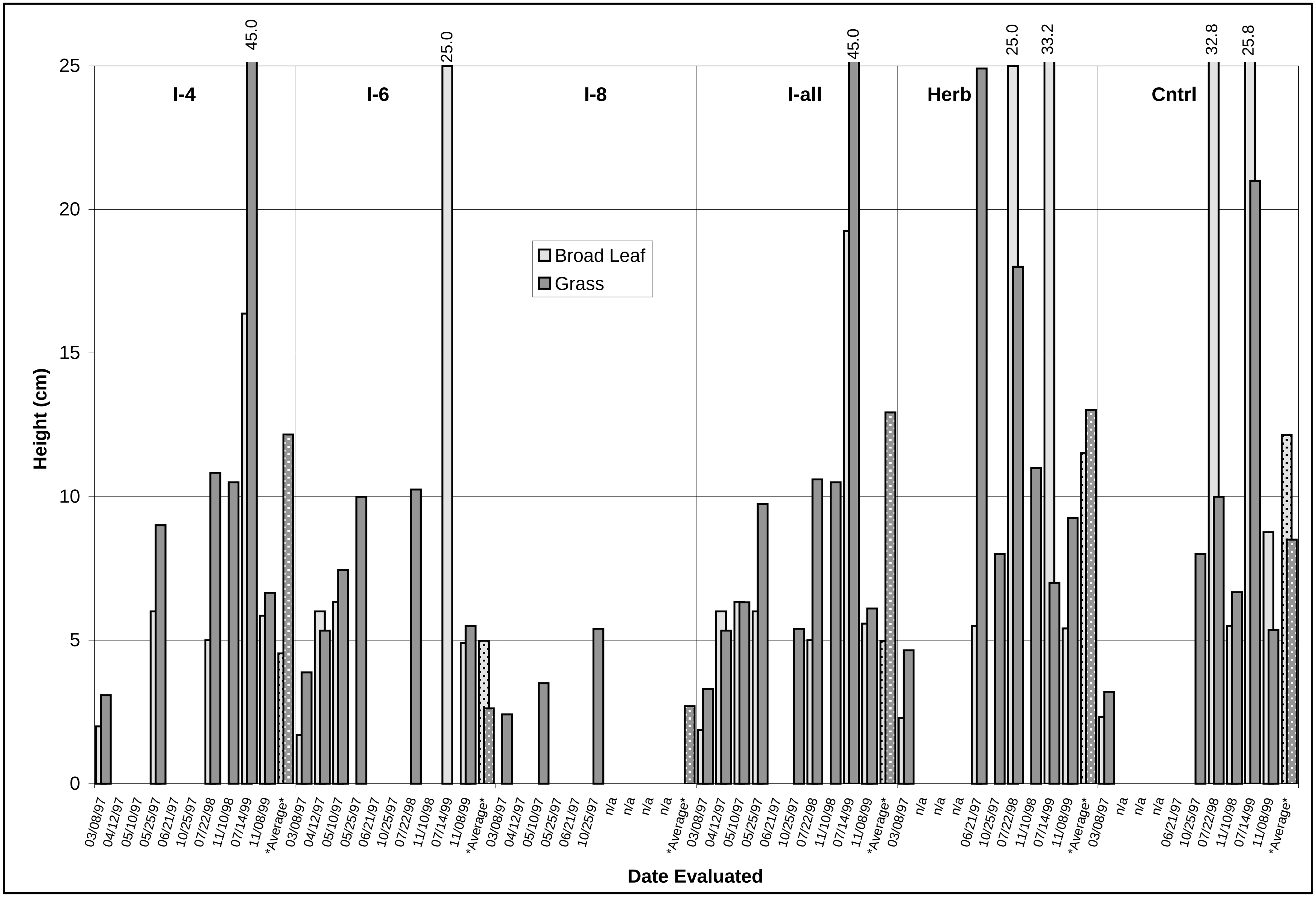


Figure 7.6: Site 1 - Plant height, grouped by treatment type

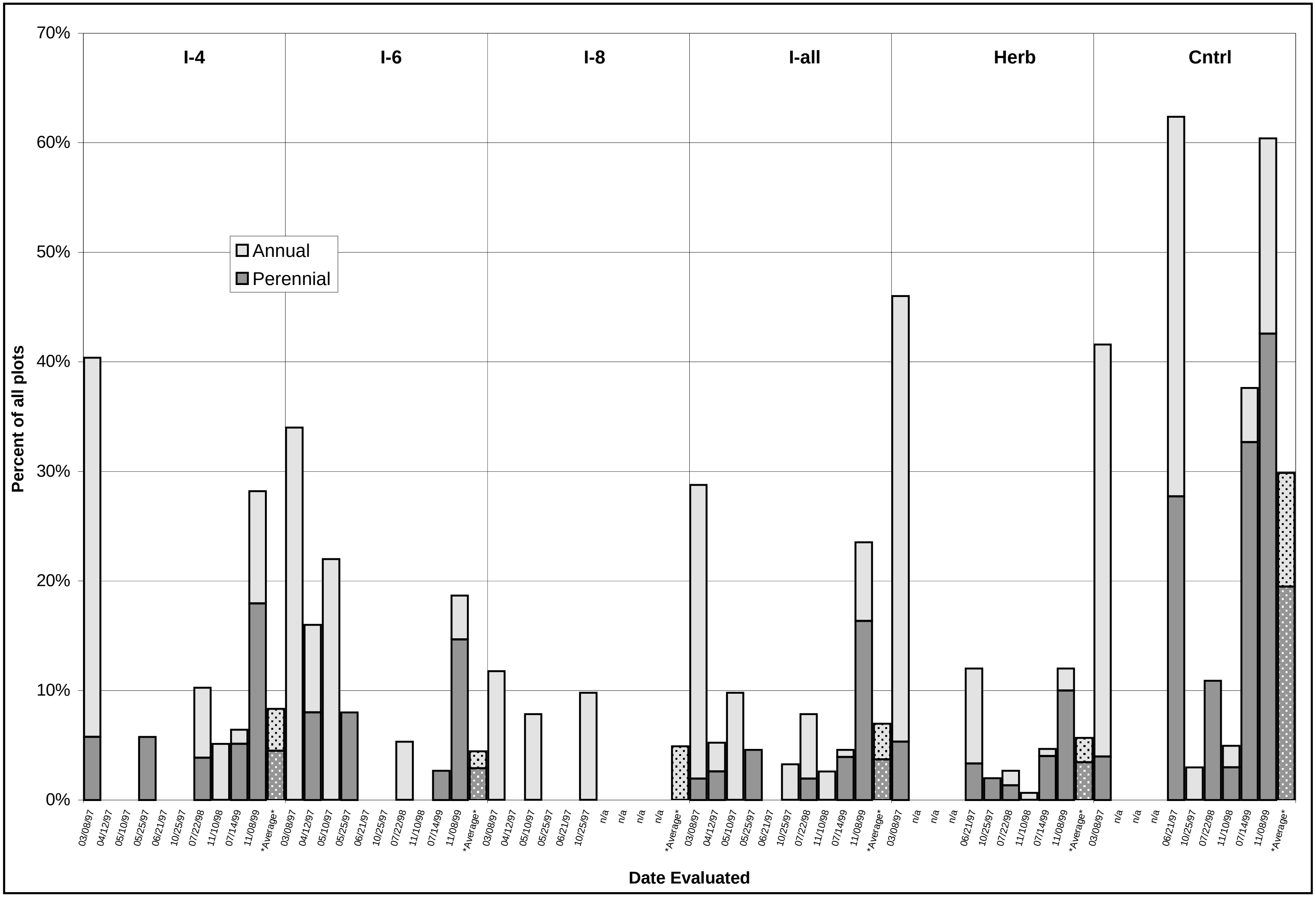


Figure 7.7: Site 1 - Percentage of annual and perennial plants

7.3.2 Site 2 (Creswell)

Compared to Site 1, this site had substantially more vegetation and rainfall. Prior to this research study, test plots at Site 2 had been treated annually with herbicides. The last treatment had occurred on 5/6/97 with a mixture of Roundup (48 oz/acre), Oust (3 oz/acre) and Krovar (6 lbs/acre).

7.3.2.1 Infrared Plots

Infrared treatments began on 3/30/98 and continued to 6/23/99. Each plot received four or six treatments per year as shown in Table 4.1.

The first evaluation, conducted on 4/27/98, showed that the vegetation coverage averaged 7.3% (6.4% grass, 1.0% broadleaf). The next evaluation on 7/13/98 revealed a small increase to 8.9% (7.0% grass, 1.9% broadleaf). The plots were evaluated again on 11/03/98 after four months of growth. The vegetation in the infrared plots had increased to 16.9% coverage (15.0% grass, 2.0% broadleaf).

In the second year (7/20/99) following the spring infrared treatments, the coverage dropped to 4.9% (4.3% grass, 0.6% broadleaf). After four months of growth the final evaluation (11/2/99) showed a coverage of 14.0% (13.1% grass, 1.0% broadleaf).

7.3.2.2 Control Plots

The control plots were evaluated on 4/27/98 and found to average 19.1% vegetation coverage (13.8% grass, 5.3% broadleaf). On 6/1/98 one of the control plots (MP 8.36 to MP 8.71) was inadvertently treated with herbicides. Subsequently, an evaluation on 7/13/98 showed that the coverage dropped to 7.1% (3.6% grass, 3.5% broadleaf). After five months of growth (11/03/98) the coverage increased to 26.0% (20.7% grass, 5.2% broadleaf). The second year (7/20/99) vegetation coverage dropped to 11.4% (4.8% grass, 6.6% broadleaf). The final evaluation (11/02/99) showed a coverage of 15.7% (9.2% grass, 6.5% broadleaf).

7.3.2.3 Herbicide Plots

At the start of the evaluation period (4/27/98) the herbicide plots had coverage of 19.6% (12.0% grass, 7.5% broadleaf). The plots were treated on 6/17/98 with Direx 4L (1.2 gal/acre), Oust (3 oz/acre), Roundup Pro (48 oz/acre) and Rodeo (48 oz/acre). Following the treatment, the evaluation on 7/13/98 showed that the coverage had decreased to 1.9% (1.3% grass, 0.6% broadleaf). After about four months of growth (11/03/98) the vegetation had grown back to 15.8% (11.9% grass, 3.9% broadleaf). Following the 1999 treatments the summer (7/20/99) coverage fell to 0.6% (0.1% grass, 0.5% broadleaf). The final evaluation (11/2/99) recorded the average coverage at 2.7% (1.1% grass, 1.6% broadleaf).

7.3.2.4 Mow Plot

The mow plot was inadvertently treated with herbicides on 6/1/98. Following this treatment, the vegetation coverage dropped from 18.9% (14.2% grass, 4.7% broadleaf) to 10.6% (7.0% grass, 3.6% broadleaf). After five months of growth (11/3/98) the vegetation grew to 34% (29.2% grass, 4.7% broadleaf). In the second year (7/20/99), the coverage started at 21.1% (7.0% grass, 14.1% broadleaf) and finished (11/2/99) at 18.2% (11.6% grass, 6.5% broadleaf). There was only one mow plot at this site, and it appeared the herbicide affected the plot in 1998.

It is interesting to note that all plots showed maximum coverage on 11/3/98, being comprised of mostly low-growing grass. This growth was unexpected, since rainfall was well below normal during the five preceding months.

In summary, the vegetation coverage on the herbicide plots ranged from 0.6% to 19.6%, with an overall average of 5.2% from 1998 to 1999. The infrared treatments resulted in an average coverage of 11.2%, where those plots receiving four treatments had 13.1% coverage and those receiving six treatments had 7.7%. (The average coverage on all infrared plots was 11.2%).

For this test period, the herbicide-treated plots and the six-treatment infrared plots would comply mostly with LOS “B” and occasionally with “C”. The four-treatment infrared plots would comply mostly with LOS “C” and occasionally with “B”.

Table 7.8: Summary of Field Evaluation Data at Site 2 (Creswell)

Treat-ment	Date	# of Sub-plots	Sub-plots w/veg	Pct w/veg	Pct Coverage by Type				Height (cm)		Life Cycle	
					BL*	GR*	S*	All	BL*	GR*	Annual	Perenn.
I-4	04/27/98	56	50	89%	1.3%	8.8%	0.0%	10.1%	2.4	3.6	0%	0%
	07/13/98		25	45%	4.0%	9.2%	0.0%	13.3%	7.1	9.1	13%	36%
	11/03/98		36	64%	3.3%	20.1%	0.0%	23.3%	5.5	8.3	16%	57%
	07/20/99		22	39%	0.6%	6.1%	0.0%	6.7%	12.0	3.9	4%	38%
	11/02/99		28	50%	1.6%	15.5%	0.0%	17.1%	18.7	6.3	5%	46%
	Average		**32.2**	**58%**	2.4%	12.7%	0.0%	**15.1%**	10.8	6.9	**9.4%**	**44.2%**
I-6	04/27/98	62	41	66%	0.7%	4.2%	0.0%	4.8%	2.6	3.0	0%	0%
	07/13/98		13	21%	0.0%	5.0%	0.0%	5.0%	na	10.1	2%	19%
	11/03/98		36	58%	0.9%	10.3%	0.0%	11.2%	9.0	4.4	18%	42%
	07/20/99		17	27%	0.5%	2.7%	0.0%	3.3%	1.8	2.2	2%	26%
	11/02/99		25	40%	0.4%	10.8%	0.0%	11.3%	4.0	4.4	11%	31%
	Average		**26.4**	**43%**	0.5%	7.2%	0.0%	**7.7%**	na	5.3	**8.1%**	**29.4%**
I-8	04/27/98	0			No I-8 plots at this site							
	07/13/98				No I-8 plots at this site							
	11/03/98				No I-8 plots at this site							
	07/20/99				No I-8 plots at this site							
	11/02/99				No I-8 plots at this site							
	Average				No I-8 plots at this site							
I-all	04/27/98	118	91	77%	1.0%	6.4%	0.0%	7.3%	2.5	0.0	0%	0%
	07/13/98		38	61%	1.9%	7.0%	0.0%	8.9%	7.1	9.5	7%	27%
	11/03/98		72	116%	2.0%	15.0%	0.0%	16.9%	6.6	6.4	17%	49%
	07/20/99		39	63%	0.6%	4.3%	0.0%	4.9%	5.9	3.2	3%	31%
	11/02/99		53	85%	1.0%	13.1%	0.0%	14.0%	11.3	5.4	8%	38%
	Average		**58.6**	**50%**	1.4%	9.8%	0.0%	**11.2%**	7.7	6.1	**8.7%**	**36.4%**
Herb	04/27/98	78	68	87%	7.5%	12.0%	0.0%	19.6%	4.5	7.7	0%	0%
	07/13/98		10	13%	0.6%	1.3%	0.0%	1.9%	6.7	8.6	4%	9%
	11/03/98		48	62%	3.9%	11.9%	0.0%	15.8%	1.3	3.5	50%	21%
	07/20/99		5	6%	0.5%	0.1%	0.0%	0.6%	3.0	7.0	3%	4%
	11/02/99		8	10%	1.6%	1.1%	0.0%	2.7%	4.9	9.7	0%	10%
	Average		**27.8**	**36%**	1.6%	3.6%	0.0%	**5.2%**	4.0	7.2	**14.1%**	**10.9%**
Mow	04/27/98	38	38	100%	4.7%	14.2%	0.0%	18.9%	4.2	7.7	0%	0%
	07/13/98		16	42%	3.6%	7.0%	0.0%	10.6%	15.3	18.4	16%	32%
	11/03/98		35	92%	4.7%	29.2%	0.0%	34.0%	3.5	4.0	71%	47%
	07/20/99		24	63%	14.1%	7.0%	0.0%	21.1%	13.4	17.1	18%	53%
	11/02/99		30	79%	6.5%	11.6%	0.0%	18.2%	4.9	4.8	26%	61%
	Average		**28.6**	**75%**	7.2%	13.7%	0.0%	**21.0%**	9.3	11.1	**32.9%**	**48.0%**
Cntrl	04/27/98	61	56	92%	5.3%	13.8%	0.0%	19.1%	4.6	6.9	0%	0%
	07/13/98		32	52%	3.5%	3.6%	0.0%	7.1%	10.5	11.9	20%	39%
	11/03/98		44	72%	5.2%	20.7%	0.0%	26.0%	4.8	8.0	54%	33%
	07/20/99		29	48%	6.6%	4.8%	0.0%	11.4%	11.1	19.3	10%	43%
	11/02/99		31	51%	6.5%	9.2%	0.0%	15.7%	1.8	9.9	23%	33%
	Average		**38.4**	**101%**	5.4%	9.6%	0.0%	**15.0%**	7.1	12.2	**26.6%**	**36.9%**

* BL = Broadleaf; G = Grass; S = Sedge

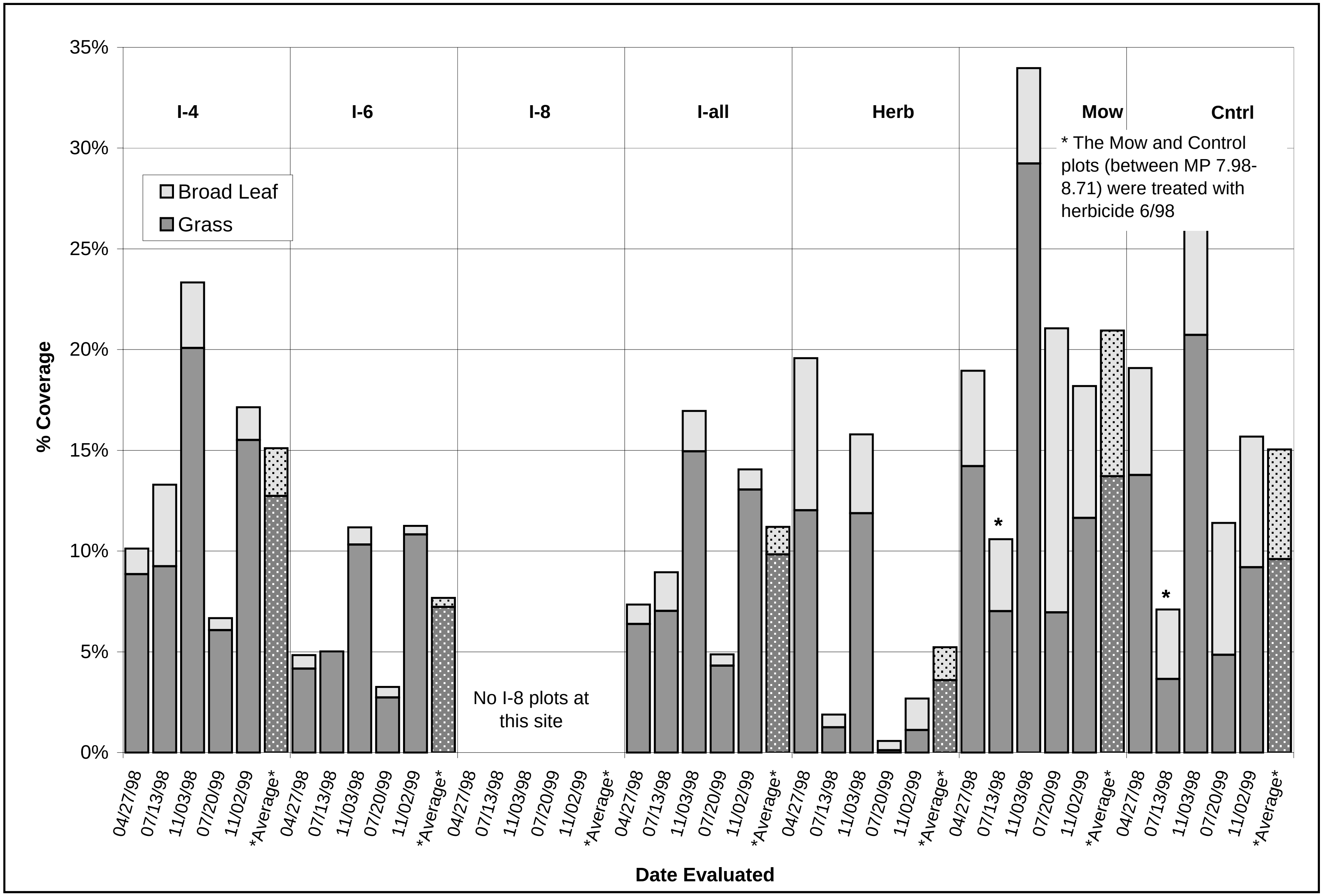


Figure 7.8: Site 2 - Percent vegetation coverage, grouped by treatment type

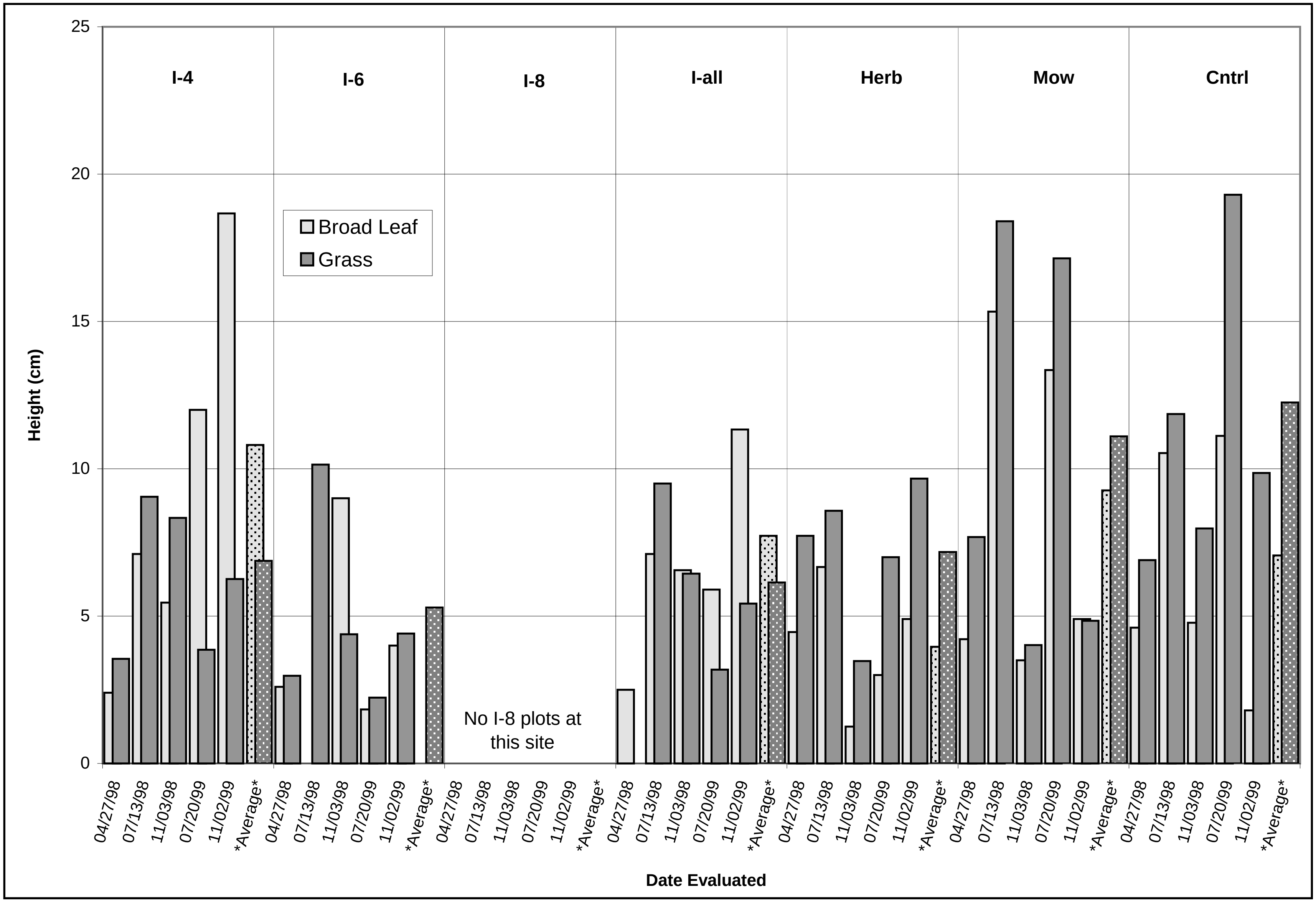


Figure 7.9: Site 2 - Plant height, grouped by treatment type

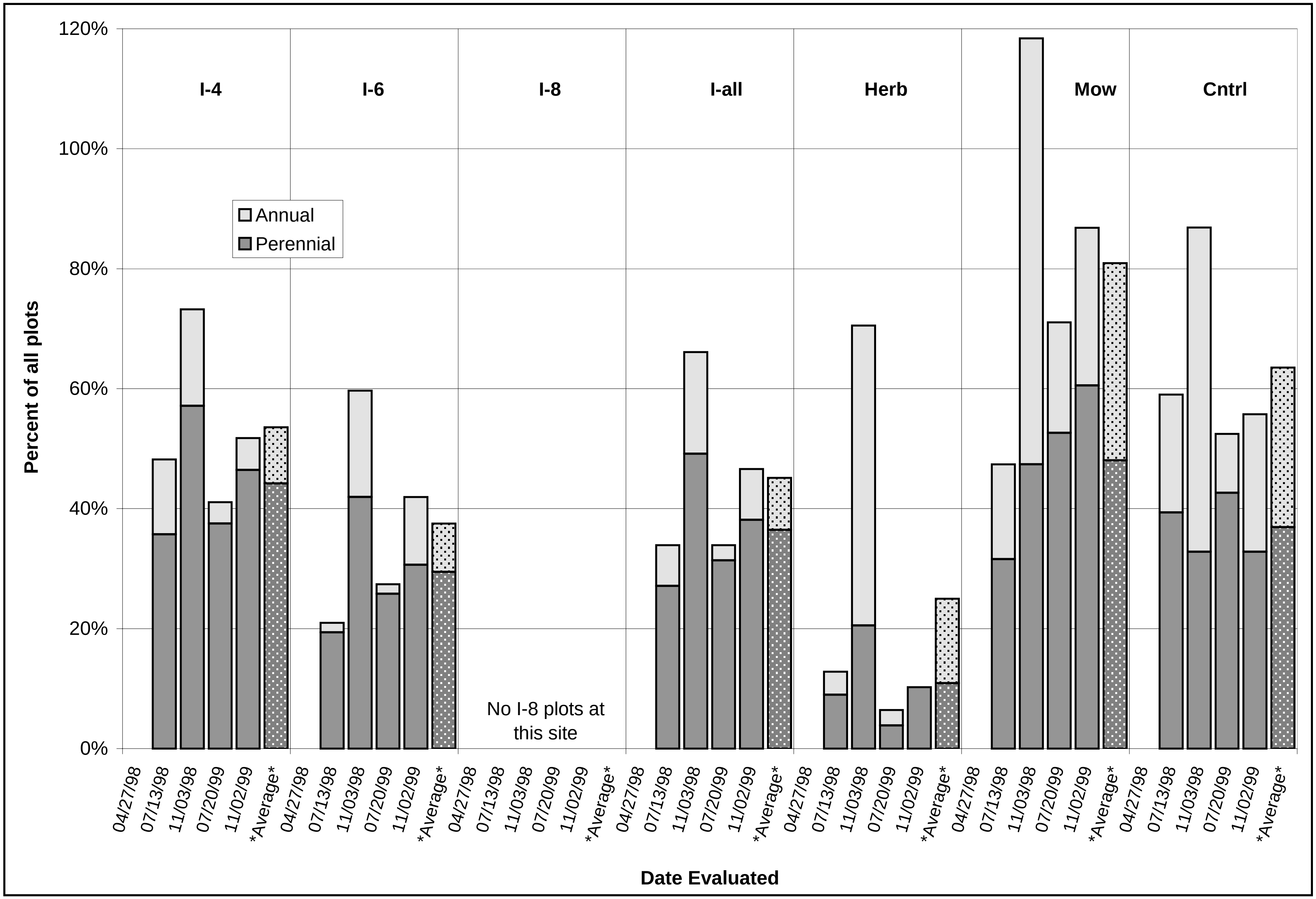


Figure 7.10: Site 2 - Percentage of annual and perennial plants

7.3.3 Site 3 (Blachly)

Compared to Sites 1 and 2, this site had substantially more vegetation and rainfall. Prior to this research study, test plots at site 3 were treated annually with herbicides until 1995. From 1996-97 herbicide use was limited to spot spray use to control only the noxious weeds. The last full treatment occurred on 4/25/95 with a mixture of Roundup (1.5 qt/acre) and Oust (4 oz/acre). Heavy rainfall caused the site to flood in the spring of 1996.

7.3.3.1 Infrared Plots

Infrared treatments began on 3/9/98 and continued to 6/30/99. Each plot received four, six or eight treatments per year as shown in Table 4.1.

The first evaluation was conducted on 4/27/98 and showed a coverage of 21.7% (11.4% grass, 10.3% broadleaf). By 6/30/98 it had decreased to 15.2% (7.6% grass, 7.6% broadleaf). The plots were evaluated again on 10/27/98 after four months of growth. The vegetation had increased to 44.6% (29.7% grass, 14.9% broadleaf).

In the second year, following the planned treatments, the 7/20/99 evaluation showed that the coverage had decreased to 8.7% (5.7% grass, 2.9% broadleaf). About three months later (10/12/99) the coverage was 25.3% (14.0% grass, 11.3 broadleaf).

7.3.3.2 Control Plots

The initial evaluation of the control plots in 1998 showed a coverage of 43.9% (28.0% grass, 15.8% broadleaf). The vegetation coverage remained between 27.8% and 43.9% during the course of the study. The final evaluation (10/12/99) showed the coverage to be 32.9% (21.6% grass, 11.2% broadleaf).

7.3.3.3 Herbicide Plots

The initial evaluation of the herbicide plots (4/27/98) showed a coverage of 44.5% (21.1% grass, 23.4% broadleaf). The plots were treated on 6/17/98 with Direx 4L (1.2 gal/acre), Oust (3 oz/acre), Roundup Pro (48 oz/acre) and Rodeo (48 oz/acre). By 6/30/98 the coverage had dropped to 22.1% (6.3% grass, 15.8% broadleaf). Following four months of growth (10/27/98) it was 23.9% (13.2% grass, 10.7% broadleaf).

In the second year, following the planned treatments, the coverage (7/20/99) was found to be 6.2% (0.7% grass, 5.5% broadleaf). After about three months (10/12/99) the evaluation showed the coverage at 9.2% (1.9% grass, 7.4% broadleaf).

7.3.3.4 Mow Plot

The mow plot had the most coverage at the start of the evaluation period with 65.9% (33.1% grass, 32.9% broadleaf, 4/27/98) coverage. The coverage then dropped to 23.7% (9.8% grass, 13.9% broadleaf, 6/30/98) and back up to 37.4% (23.8% grass, 13.6% broadleaf, 10/27/98). In 1999, the coverage remained relatively the same and then finished (10/12/99) at 33.8% (22.5% grass, 11.4% broadleaf). The mow plot appeared to have more shade and moisture, which could be one reason for the higher coverage.

In summary, the herbicide plots ranged from 6.2% to 44.5% vegetation coverage and an overall average of 15.3% from 1998 to 1999. The plots receiving infrared treatments resulted in averages of 23.3%, 22.2% and 26.2% coverage for the four-, six- and eight-treatment plots, respectively.

For this test period, the herbicide plots would comply between LOS “B” and “C”. The infrared plots would mostly be at LOS “C” and occasionally at “B”.

Table 7.9: Summary of Field Evaluation Data at Site 3 (Blachly)

Treat-ment	Date	# of Sub-plots	Sub-plots w/veg	Pct w/veg	Pct Coverage by Type				Height (cm)		Life Cycle	
					BL*	GR*	S*	All	BL*	GR*	Annual	Perenn.
I-4	04/27/98	47	46	98%	13.1%	17.4%	0.0%	30.4%	6.1	8.5	0%	0%
	06/30/98		32	68%	6.6%	10.0%	0.0%	16.6%	3.6	5.4	15%	66%
	10/27/98		40	85%	16.0%	24.1%	0.0%	40.1%	7.0	7.7	32%	70%
	07/20/99		23	49%	3.2%	6.3%	0.0%	9.5%	2.5	4.7	23%	32%
	10/12/99		25	53%	12.6%	14.3%	0.0%	26.9%	6.4	5.2	9%	49%
	Average		**33.2**	**71%**	9.6%	13.7%	0.0%	**23.3%**	4.9	5.8	**19.7%**	**54.3%**
I-6	04/27/98	51	47	92%	10.1%	7.9%	0.0%	18.0%	4.6	5.7	0%	0%
	06/30/98		36	71%	9.6%	7.3%	0.0%	16.9%	4.6	5.6	14%	63%
	10/27/98		47	92%	12.9%	29.1%	0.0%	41.9%	4.0	7.0	25%	88%
	07/20/99		21	41%	3.5%	5.1%	0.0%	8.6%	7.8	6.4	2%	41%
	10/12/99		26	51%	8.3%	13.0%	0.0%	21.3%	7.6	5.6	14%	45%
	Average		**35.4**	**69%**	8.6%	13.6%	0.0%	**22.2%**	6.0	6.2	**13.7%**	**59.3%**
I-8	04/27/98	25	18	72%	5.4%	7.5%	0.0%	12.9%	3.8	5.1	0%	0%
	06/30/98		18	72%	5.2%	3.6%	0.0%	8.8%	6.5	3.8	20%	64%
	10/27/98		24	96%	17.2%	41.2%	0.0%	58.5%	8.2	10.5	16%	96%
	07/20/99		8	32%	1.3%	5.9%	0.0%	7.2%	4.5	5.1	8%	24%
	10/12/99		22	88%	14.8%	15.5%	0.0%	30.3%	8.7	7.5	28%	64%
	Average		**18.0**	**72%**	9.7%	16.5%	0.0%	**26.2%**	7.0	6.8	**18.0%**	**62.0%**
I-all	04/27/98	123	111	90%	10.3%	11.4%	0.0%	21.7%	5.0	6.9	0%	0%
	06/30/98		86	70%	7.6%	7.6%	0.0%	15.2%	4.6	5.2	15%	64%
	10/27/98		111	90%	14.9%	29.7%	0.0%	44.6%	5.8	8.0	26%	83%
	07/20/99		52	42%	2.9%	5.7%	0.0%	8.7%	5.5	5.4	11%	34%
	10/12/99		73	59%	11.3%	14.0%	0.0%	25.3%	7.5	5.8	15%	50%
	Average		**86.6**	**70%**	9.2%	14.2%	0.0%	**23.4%**	5.8	6.1	**16.9%**	**57.9%**
Herb	04/27/98	67	58	87%	23.4%	21.1%	0.0%	44.5%	11.3	12.9	0%	0%
	06/30/98		24	36%	15.8%	6.3%	0.0%	22.1%	26.5	17.4	3%	33%
	10/27/98		45	67%	10.7%	13.2%	0.0%	23.9%	16.6	7.4	24%	45%
	07/20/99		18	27%	5.5%	0.7%	0.0%	6.2%	13.9	15.3	6%	22%
	10/12/99		26	39%	7.4%	1.9%	0.0%	9.2%	7.0	12.5	7%	36%
	Average		**34.2**	**51%**	9.8%	5.5%	0.0%	**15.3%**	16.0	13.1	**10.1%**	**34.0%**
Mow	04/27/98	24	24	100%	32.9%	33.1%	0.0%	65.9%	11.1	16.9	0%	0%
	06/30/98		19	79%	13.9%	9.8%	0.0%	23.7%	10.4	13.8	42%	58%
	10/27/98		24	100%	13.6%	23.8%	0.0%	37.4%	8.2	15.8	29%	88%
	07/20/99		18	75%	19.9%	23.0%	0.0%	42.9%	13.3	18.2	13%	75%
	10/12/99		20	83%	11.4%	22.5%	0.0%	33.8%	3.4	11.1	42%	58%
	Average		**21.0**	**88%**	14.7%	19.8%	0.0%	**34.5%**	8.8	14.7	**31.3%**	**69.8%**
Cntrl	04/27/98	65	64	98%	15.8%	28.0%	0.0%	43.9%	10.4	17.6	0%	0%
	06/30/98		58	89%	16.9%	22.6%	0.0%	39.5%	12.8	31.4	20%	80%
	10/27/98		63	97%	7.9%	33.9%	0.0%	41.8%	6.1	13.3	23%	82%
	07/20/99		51	78%	13.0%	14.7%	0.0%	27.8%	16.9	16.1	20%	65%
	10/12/99		46	71%	11.2%	21.6%	0.0%	32.9%	9.9	12.1	23%	55%
	Average		**56.4**	**87%**	12.3%	23.2%	0.0%	**35.5%**	11.4	18.2	**21.5%**	**70.4%**

* BL = Broadleaf; G = Grass; S = Sedge

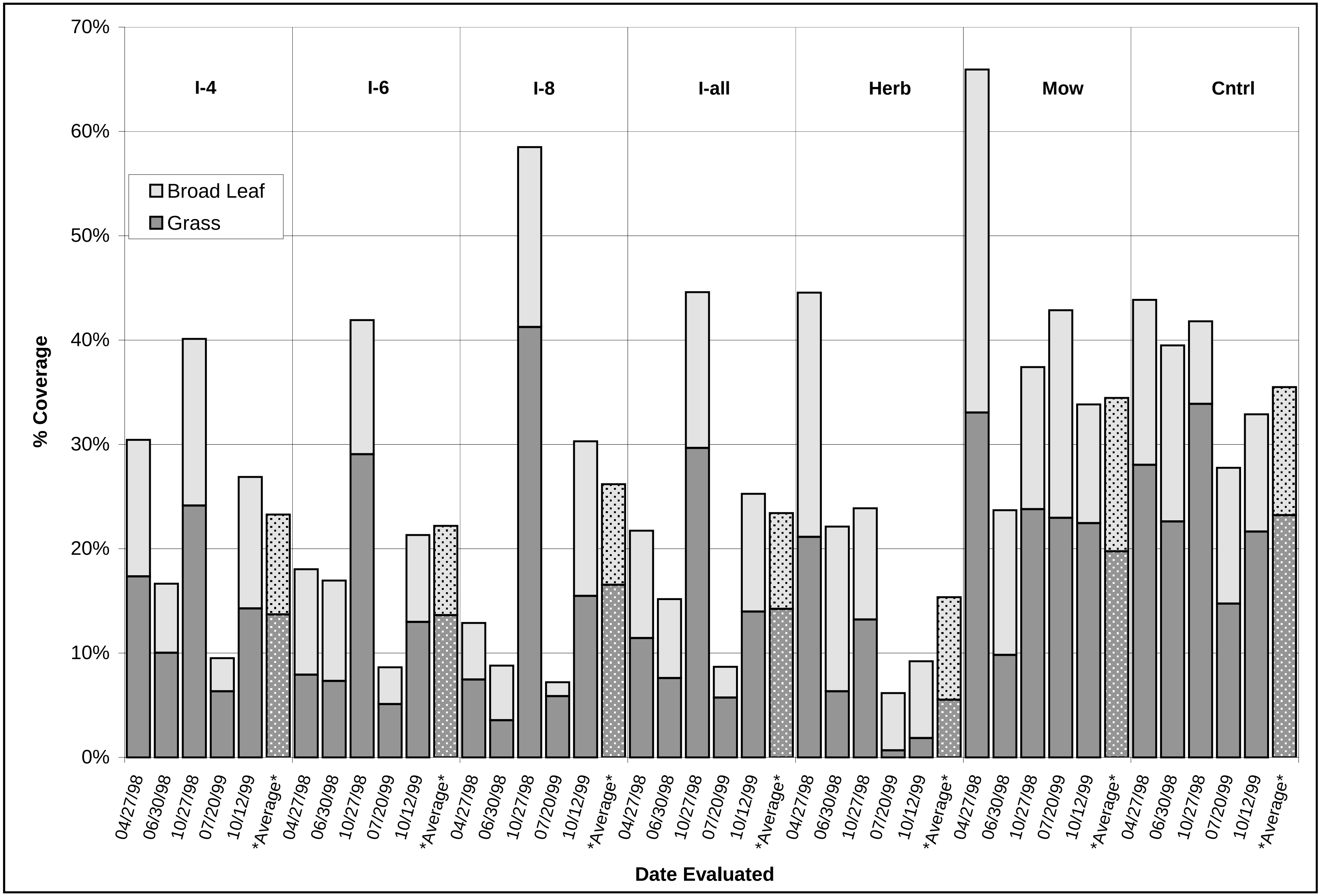


Figure 7.11: Site 3 - Percent vegetation coverage, grouped by treatment type

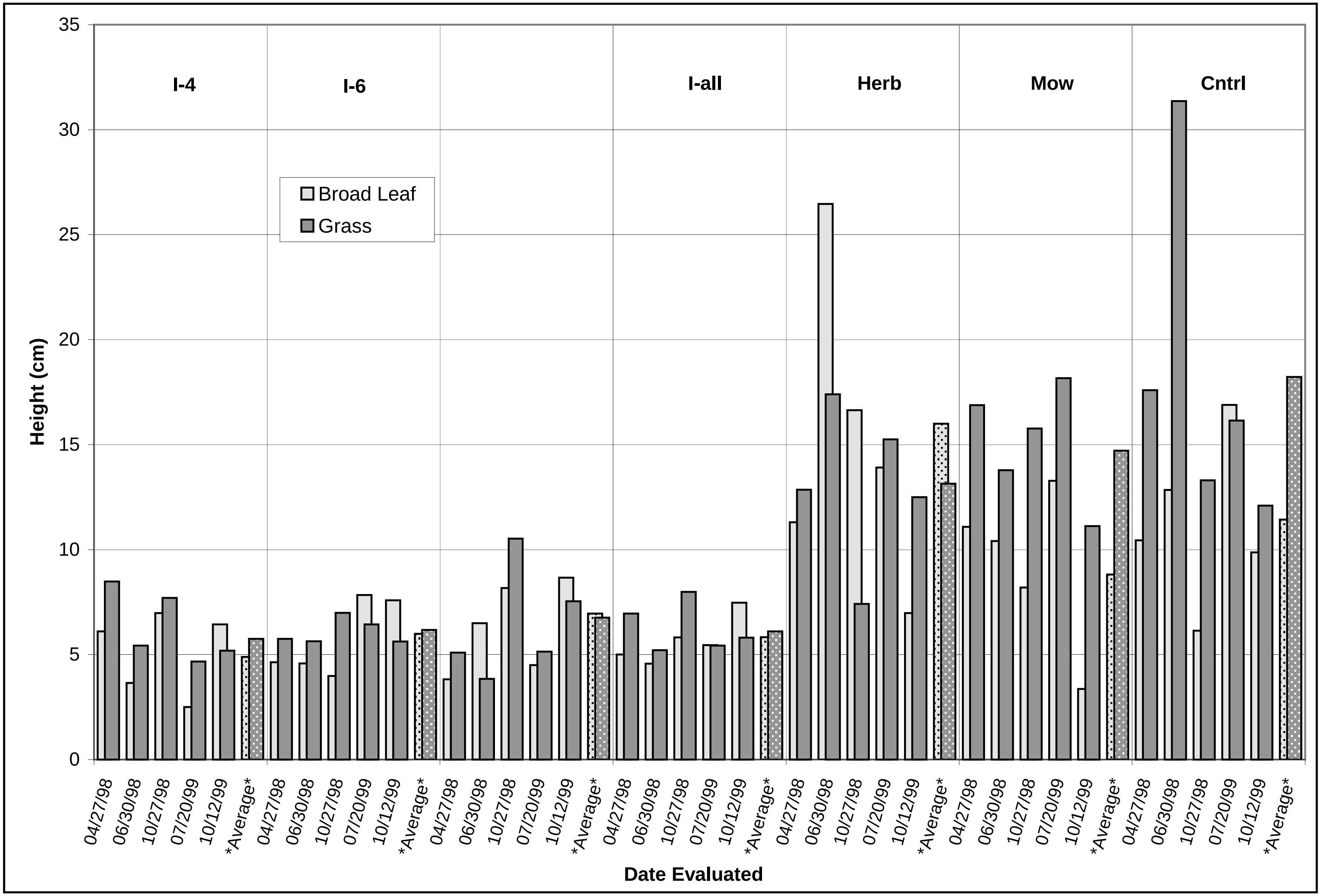


Figure 7.12: Site 3 - Plant height, grouped by treatment type

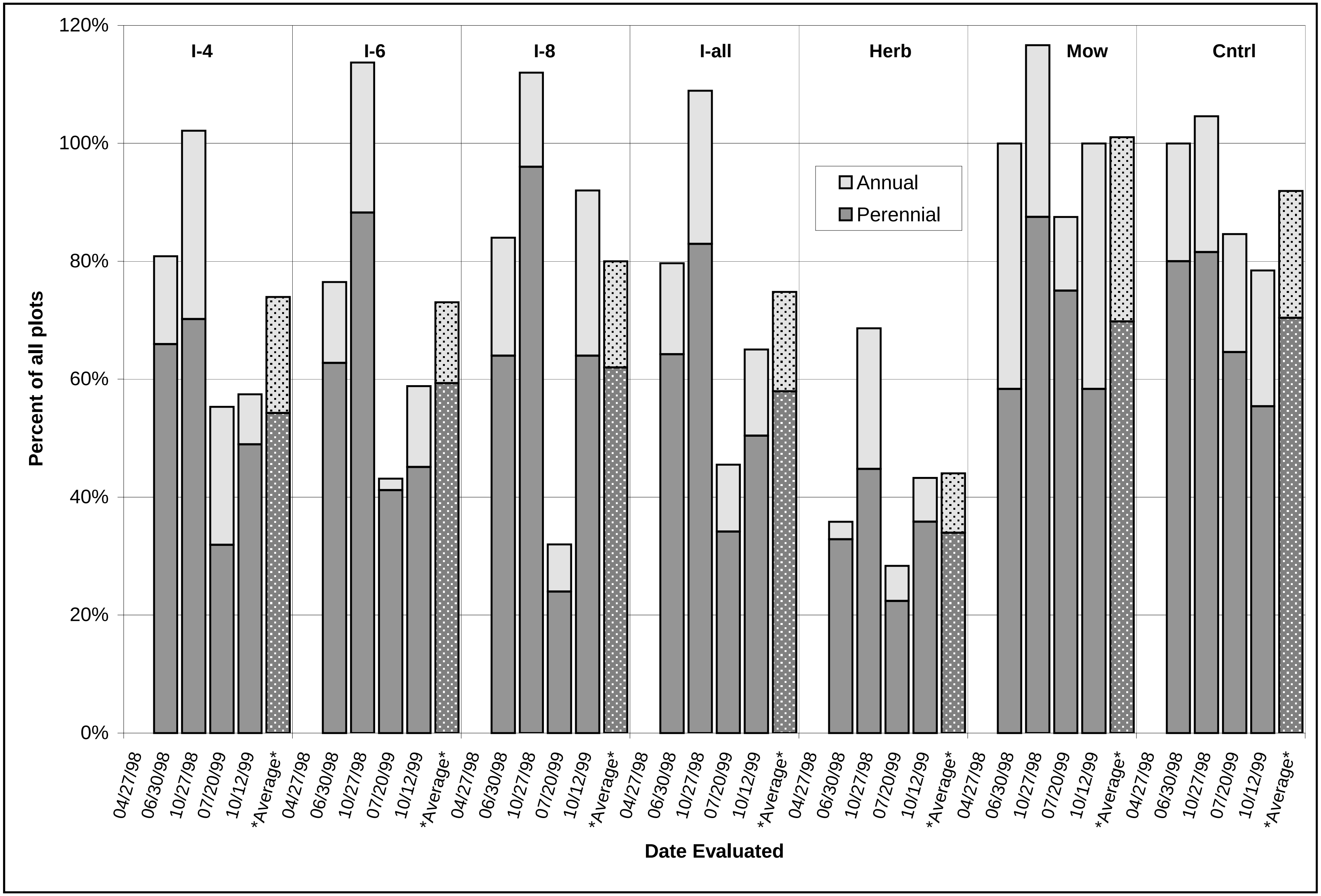


Figure 7.13: Site 3 - Percentage of annual and perennial plants

7.3.4 Summary

Below is a summary of the observations for the three sites.

7.3.4.1 General Observations (all sites)

- 1996 & 1998: Annual precipitation was above normal; summer precipitation was at or below normal (Sites 1 and 2 were below normal; Site 3 was normal).
- 1997: Annual precipitation was normal; summer precipitation was at or above normal (Site 1 was normal, Sites 2 and 3 were above normal).
- Grass coverage was generally more than the broadleaf coverage.
- No sedge was found at any site.
- Perennials were more common than annuals.

7.3.4.2 Site 1 Observations

- The average vegetation coverage was 1% (Infrared-4 plots), 0.5% (Infrared-6 plots), 2% (Herbicide plots) and 10% (Control plots).
- The last measured coverage (11/8/99) was 4% (Infrared-4 plots), 2% (Infrared-6 plots), 3% (Herbicide plots) and 13% (Control plots).
- The highway shoulders were bladed before the 10/97 evaluation, leaving very little vegetation: the Control plots coverage dropped from 30% (6/97) to 1% (10/97).
- The coverage in 1998 decreased due to low summer rainfall. In 1999 the coverage increased from July to October.
- The Infrared plots receiving six treatments provided best control of vegetation, resulting in 0.5% average coverage during the course of the study and 2.4% coverage at the end (11/8/99).
- The Herbicide and Infrared Plots complied in most cases with LOS “B”.

7.3.4.3 Site 2 Observations

- The average vegetation coverage was 15% (Infrared-4 plots), 8% (Infrared-6 plots), 5% (Herbicide plots), 21% (Mow plot) and 15% (Control plots).
- The last measured coverage (11/2/99) was 17% (Infrared-4 plots), 11% (Infrared-6 plots), 3% (Herbicide plots), 18% (Mow plot) and 16% (Control plots).
- For broadleaf vegetation the average coverage was 1% (Infrared), 2% (Herbicide), 7% (Mow) and 5% (Control).
- For grasses the average coverage was 10% (Infrared), 4% (Herbicide), 14% (Mow) and 10% (Control).
- Grasses were more common as shoulder vegetation than broadleaf plants.
- Coverage increased both years (1998 and 1999) in the July - October period.
- The Infrared plots receiving six treatments provided better control (leaving 8% coverage) than those receiving four treatments (leaving 15% coverage). Very little of the vegetation consisted of broadleaf plants; it was comprised mostly of grasses.

- Infrared-4 treatments (15%) netted the same average coverage as no treatment (15%); but most of the vegetation remaining on Infrared-4 plots was grass, which is considered to be more aesthetically pleasing than broadleaf plants.
- Infrared treatments controlled vegetation well during the spring - summer period (5-9% average coverage), but growth returned in fall (14-17% average coverage).
- The height of vegetation was lowest in the plots receiving infrared and herbicide treatments (both at 6 cm average), followed by the Control and Mowing plots (both at 10 cm).
- The Herbicide plots and Infrared-6 plots complied with LOS "B". The Infrared-4 plots complied with LOS "C".

7.3.4.4 Site 3 Observations

- The average vegetation coverage was 23% (Infrared plots), 15% (Herbicide plots), 34% (Mow plot) and 35% (Control plots).
- The last measured coverage (10/12/99) was 25% (Infrared plots), 9% (Herbicide plots), 34% (Mow plot) and 33% (Control plots).
- For broadleaf vegetation the average coverage was 9% (Infrared), 10% (Herbicide), 15% (Mow) and 12% (Control).
- For grasses the average coverage was 14% (Infrared), 5% (Herbicide), 20% (Mow) and 23% (Control).
- Grasses were more common than broadleaf vegetation.
- Coverage increased both years (1998 and 1999) in the July - October period, although the Herbicide plots and the Control plots showed only slight increases.
- Mowing resulted in about the same average coverage as the Control plots (no treatment).
- The height of vegetation was lowest in the plots receiving infrared treatments (6 cm average), followed by the Mowing plots (12 cm), the Herbicide plots (15 cm), and the Control plots (16 cm).
- The Herbicide and Infrared plots ranged from LOS "B" to "C", although the Herbicide plots were closer to "B".

7.4 NOXIOUS WEED COUNTS

Noxious weeds were identified and counted in 140 sub-plots, or two within each plot. The count occurred during the July 1998, November 1998, July 1999 and November 1999 evaluations. Table 7.10 summarizes the incidence of noxious weeds in the sub-plots.

At Site 1, there were a total of 65 sub-plots used in the count. Of those, 19 contained noxious weeds during at least one evaluation. The vegetation at Site 1 was sparse, and the number of noxious weeds was also low. None of the infrared- or herbicide-treated plots contained any recurring weeds. Among the nine Control subplots containing weeds, three had recurring St. Johnswort or Knapweed.

At Site 2, there were 32 sub-plots used in the count, and seven contained noxious weeds during at least one evaluation. None of the infrared or herbicide treated plots contained any recurring weeds. Among the two Control plots with weeds, one had a recurrence of field bindweed.

At Site 3, there were 43 sub-plots used in the count, and 34 contained noxious weeds during at least one evaluation. Four out of twelve Infrared sub-plots had recurrences of knapweed and horsetail. Subplot B@100S had an increasing number of horsetail with a final coverage of 10% on 11/2/99. Four out of eleven Herbicide sub-plots had recurring knapweed or horsetail. Three out of seven Control sub-plots had recurring knapweed or scotch broom; however, these consisted of only 1 to 3 plants.

Table 7.10: Noxious Weeds

Site 1	**Sub-plot**	**7/22/1998**	**11/10/1998**	**7/14/1999**	**11/08/1999**
I-4	3E@100		Lots of horseweed scattered throughout this area		
I-4	5H@700	1 Yellow starthistle			
I-4	2H@100		Lots of blackberries reaching to the edge of the road		
I-4	3B@100		1 Yellow starthistle		
I-6	2B@700		17 crabgrass		
I-6	5E@700	1 St. Johnswort			
Herb	2A@100		Lots of blackberries		
Herb	2C@100			1 St. Johnswort	
Herb	2C@700		Lots of blackberries		
Herb	3C@100			2 Horsetail	
Cntrl	1G@100				1 Meadow Knapweed
Cntrl	1G@700	2 Yellow starthistle, 3 St. Johnswort	2 St. Johnswort	1 St. Johnswort	
Cntrl	2D@100		1 crabgrass		
Cntrl	2D@700	2 St. Johnswort	5 St. Johnswort, 1 Russian knapweed	1 Knapweed	1 Meadow Knapweed
Cntrl	2G@700				10 Yellow Starthistle
Cntrl	3D@100			4 St. Johnswort	
Cntrl	3G@100			3 St. Johnswort	
Cntrl	5D@700	13 St. Johnswort		4 St. Johnswort	
Cntrl	5G@100	1 Yellow starthistle			

Site 2	**Subplot**	**7/13/1998**	**11/03/1998**	**7/20/1999**	**11/02/1999**
I-4	D@100E		2 Bull thistle		10 Field bindweed
I-6	E@1000E				6 Field bindweed
I-6	E@1000W		2 Bull thistle		
Herb	A@1300W		80% Crabgrass coverage, 3 St Johnswort		
Mow	B@100E				
Cntrl	C@900E	2 Field bindweed	7 Field bindweed	1 Knapweed	2 Bull thistle
Cntrl	G@50E				2 Bull thistle

Table 7.10 (continued): Noxious Weeds

Site 3	Subplot	6/30/1998	10/27/1998	7/20/1999	10/12/1999
I-4	E@50N		1 Knapweed		
I-4	E@350N		1 Knapweed		
I-4	E@50S	9 Buckhorn plantain *	3 Russian knapweed		4 Meadow knapweed
I-4	E@350S	5 Buckhorn plantain *			
I-4	J@700S				8 Meadow knapweed
I-6	C@100S	14 cm clump Buckhorn plantain *			
I-6	C@700S	3 Buckhorn plantain *; Wild carrot *; 2 Bull thistle			
I-6	I@300S		1 Knapweed		
I-8	B@100N	7 Horsetail	20 Horsetail		
I-8	B@700N	33 Horsetail	12 Horsetail	15 Horsetail	
I-8	B@100S		15 horsetail	30 Horsetail	10% Horsetail
I-8	B@700S	19 Horsetail			
Herb	A@100N	1 Ripgut brome *; 10% Red sorrel *; 79 Horsetail			
Herb	A@100S	3 Horsetail; 10% Rattail fescue *			
Herb	A@700S	9 Rattail fescue *; 2 Hare barley *			
Herb	F@70N	1 Meadow knapweed; numerous Horsetail	1 Knapweed		1 Meadow knapweed
Herb	F@420N	1 Bull thistle; 2 Meadow knapweed	3 Knapweed; 2 spreading dogbane		
Herb	F@80S	St.Johnswort; Curly dock *; Buckhorn plantain *; Horsetail; Bentgrass *; Velvetgrass *; Red sorrel *; Rattail fescue *			
Herb	F@490S	5 Cheat *; Mayweed chamomile *; Rattail fescue *	3 Knapweed		
Herb	K@100N	11 Horsetail	>100 Horsetail		
Herb	K@700N	3 St. Johnswort	38 Horsetail		
Herb	K@100S	7 Meadow knapweed; 121 Horsetail			
Herb	K@700S	3 Horsetail	6 Horsetail	52 Horsetail	3 Meadow knapweed
Mow	G@100N		2 Scotch broom, 2 Knapweed		
Mow	G@700N	1 Field bindweed	2 Knapweed		
Mow	G@100S				3 Meadow knapweed
Mow	G@700S		1 Knapweed		1 Meadow knapweed

Table 7.10 (continued): Noxious Weeds

Site 3	Subplot	6/30/1998	10/27/1998	7/20/1999	10/12/1999
Cntrl	D@100N	1 Meadow knapweed	1 Knapweed	1 Knapweed	1 Scotch broom
Cntrl	D@700N		1 Tansy ragwort	2 St. Johnswort, 2 knapweed	
Cntrl	D@100S	27 Red sorrel *; 15 Buckhorn plantain*; Bentgrass *; Scotch broom	1 St Johnswort; 1 Scotch broom		
Cntrl	D@700S	5 Velvetgrass *; 4 Buckhorn plantain *			5 Scotch broom
Cntrl	H@100N	Meadow knapweed; 3 Canada thistle	3 Knapweed		1 Diffuse knapweed
Cntrl	H@1100N				12 Meadow Knapweed; 1 Bull thistle
Cntrl	H@1000S		7 Knapweed		

* This vegetation is not listed as a noxious weed but is considered an undesirable weed.
NOTE: Shaded items show recurring weeds in the same sub-plot.

8.0 LABOR, EQUIPMENT AND MATERIALS

This study was conducted using an early prototype infrared device. Although the design of such devices will probably change, it is of interest to examine the labor, equipment and materials used in the study.

The operating cost of the infrared device is controlled largely by its speed of the operation, which affects the exposure time and heat transfer. The most effective exposure time depends on the vegetation type, density, moisture conditions, temperature and wind. As noted earlier, the speed utilized during this study varied from 1 to 3 mph (1.5-5 km/h). Future equipment improvements may produce more efficient devices, using less fuel and attaining greater speeds.

In addition, this study called for full treatment of the entire shoulder length, whether it contained vegetation or not. In a more practical operation, bypassing the bare areas would lower the average cost per mile.

Due to the narrow shoulder widths and equipment configuration, the operation traveled in the travel lanes of the roadway. Traffic control was required to protect the crew and motorist due to the operation's speed and traffic volumes. The need for flaggers and traffic control devices will vary depending of the work area location and type of highway.

The labor, equipment and materials used in this study are shown below.

<u>Labor</u>

- 1 infrared equipment operator
- 1 fire control laborer
- 1 support truck driver (also providing backup fire control)
- 2 flaggers (with traffic control devices)

<u>Equipment</u>

- 1 tractor with attached infrared deck and fuel tanks
- 1 support truck with water tank and fire suppression equipment
- 1 trailer to transport tractor

The bid cost to perform the infrared treatments in this study ranged from $0.08 to $0.13 per square meter for each treatment. The cost will vary depending on the factors discussed above, plot size and location. The cost does not include mobilization or flagger control.

Materials

Table 8.1: Propane Usage

Site	Propane Usage In gallons/shoulder mile (liters/km)		
	1997	1998	1999
1 (Provolt)	5.9 (13.9)	9.9 (23.3)	na
2 (Creswell)	na	7.75 (18.2)	na
3 (Blachly)	na	9.4 (22.1)	na
Average	5.9 (13.9)	9.0 (21.2)	7.6 (17.9)
3 yr average	6.8 (16.0)		

Operations performed during fire season are subject to additional requirements imposed by the State Forester. These include the following:

- Each vehicle and piece of power machinery shall be equipped with at least one 4-BC fire extinguisher that is readily visible and ready for instant use. Each vehicle will also have at least one round pointed #O type shovel (or larger) and one Pulaski. There needs to be enough fire tools such that each person on the operation will have one.
- A watchman service will be required to be on site of the operation for at least 3 hours after the operation shuts down. They must be physically capable and experienced in operating the fire equipment and have access to communications to summon assistance.
- A tank truck with at least 300-gallon (1.14m^3) capacity left on site until after watchman service is complete.
- Water pump that can pump at least 20 gal/min (76 liter/min).
- At least 500 feet (150m) of hose greater than ¾-inch (19mm) diameter and a nozzle with an inside diameter at least ¼-inch (6.4mm).

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

Controlling vegetation along the highways and ditches is necessary to maintain the integrity of the roadway and the safety of the motorist. Vegetation control is becoming increasingly difficult, however, due to various environmental rules, regulations, public concerns and funding limitations. Highway maintenance crews are continually seeking alternate methods to perform this task more efficiently.

The treatment methods are generally determined by an Integrated Vegetation Management (IVM) Plan. The plan is prepared in advance by maintenance personnel. The treatments may include herbicide spraying, mowing, shoulder blading, hand labor, and planting of competing native vegetation. In some areas, the shoulder may be left untreated if the vegetation doesn't pose a problem. Each vegetation control method has its benefits and detriments, and IVM practices are used to select the appropriate method of control.

This study found that infrared treatments repeated 4 to 6 times annually provided acceptable roadside vegetation control at two sites. In the drier region of Site 1, infrared treatments performed as well as herbicide treatments, keeping the average vegetation coverage below 2%. In the wetter region of Site 2, six treatments were needed to limit coverage to 7%. By comparison, the herbicide treatments resulted in 5% coverage, and mowing resulted in 21% coverage.

Site 3 presented a challenge for infrared treatments, because the vegetation was essentially out of control as the treatments began. This site also had high precipitation levels. After two years of infrared treatments, the vegetation coverage averaged 20-25%. By comparison, herbicide treatments resulted in 15% coverage, and mowing resulted in 34% coverage.

The timing of the infrared treatments will impact the effectiveness of the treatment. Some vegetation may lack foliage if treated too early in the year. If treated too late, the roots will have an opportunity to become better established or the plant may produce seeds. Seasonal precipitation, growth patterns and growth rates are factors that should be considered in determining the best timing for infrared treatments.

Equipment speed is also an important variable in infrared treatments. Establishing the proper exposure time is dependent on the vegetation type, density, moisture conditions, temperature and wind.

Infrared treatment could be a useful tool in the IVM program, especially where other forms of treatment are restricted or controversial. Other control methods have their own advantages and disadvantages, as shown below. Table 9.1 summarizes potential environmental concerns for each treatment.

- Herbicides may be used where it is cost effective and does not impose an environmental threat. But the use of herbicides is often a controversial issue. Some pesticides are harmful to animal species, and some persons claim undesirable or life-threatening sensitivities to the chemicals. The effect of pesticides on humans and animals is not entirely understood, and care should be taken when they are applied near waterways, populated lands, endangered plants or endangered animal territories. Some landowners request the shoulders along their property to be designated as "no-spray" zones to avoid contact with the herbicide. Other landowners support the use of ODOT-applied herbicides near their properties to reduce the spread of weeds onto their properties.

- Mowing controls the height of vegetation and is effective in reducing fire hazards and visual obstructions. Unlike herbicides or infrared treatments it is not intended to eradicate vegetation. In many cases it is desirable to retain the vegetation to provide landscaping, erosion control, sediment filtering or compete with invasive weeds. Repeated mowing may be able to eradicate some plant types, but not all types. It may not be adequate treatment for some noxious weeds. It is usually the primary vegetation control method in herbicide restricted areas.

- Shoulder blading is effective in reducing and suppressing vegetation growth, as was demonstrated by the accidental treatment at Site 1. The operation is usually performed every 2-4 years to repair pavement drop-off caused by erosion. When performed near streams, however, the operation could generate sediments that affect fish habitat. The cultivated soil condition resulting from shoulder blading is also vulnerable to noxious weed invasion.

- Hand labor is labor intensive and may not eradicate some deep-rooted vegetation. This method may be necessary, however, around endangered plant species, over rough terrain or in areas inaccessible to equipment.

- Planting regional native vegetation is starting to be used widely by ODOT. Climates with wet and warm conditions make it easy to establish native plants, but these conditions are also favorable for undesirable plants. Establishing native vegetation can be difficult in arid regions. It may take some native vegetation several years to become established and have sufficient coverage to compete with undesirable vegetation. Native vegetation may not be practical in areas prone to frequent shoulder blading or other disturbances.

- Ditch maintenance – Maintaining ditches and culverts presents unusual challenges. Vegetation in ditches traps sediment and reduces ditch capacity. But vegetation also has its benefits by providing desirable filtration to runoff water before it reaches the receiving waters of a stream or river. Mechanical excavation may be performed to remove the excess material, followed by reseeding. The mechanical excavation, however, creates sediment and debris that could affect the receiving waters and hamper fish habitat. Mowing may be performed instead of excavation to restore ditch flow, but the cuttings add debris and nutrients to the streams, increasing the growth of algae and reducing the dissolved oxygen needed for stream ecological systems. Applying herbicides to ditches directly over the water may also be harmful to fish habitats.

Table 9.1: Environmental Concerns with Vegetation Control Methods

Treatment Type	Effectiveness	Cost/mile	Environmental Concerns
Infrared	Good-Excellent	High	Smoke emissions and fire risk
Herbicide	Excellent	Low	Some chemical may be toxic to wildlife and people.
Mowing	Low	Moderate	Vegetation debris indirectly harmful to aqua ecosystems – lowering dissolved oxygen levels.
Blading	Excellent	Moderate-High	Sediment could be harmful to aqua ecosystems. Disturbed soil is vulnerable to noxious weed invasion.
Hand Labor	Moderate-Low	High	None
Native Vegetation	Moderate	Moderate	None

9.2 RECOMMENDATIONS

Infrared equipment should be considered as a potential tool in the IVM program. Training is recommended in the safe use of the equipment and in proper fire suppression techniques. Acquisition of additional fire suppression equipment may be required.

In Oregon, the operation will require a fire permit when used inside or within 1/8 mile (0.2km) of a forest protection district (as required under ORS 477.225). To reduce the risk of fire, infrared treatment should be avoided or used with extreme caution during fire season (ORS 477.505). Additional water supply and equipment may be imposed by the State Forester if the operation occurs during fire season (ORS 477.615). Excerpts of the fire protection statutes and rules are shown in Appendix G.

Specific areas for use are not suggested at this time, as this method is still new for ODOT, and experience will eventually determine the most appropriate use of this technology. There are many factors to consider when selecting a treatment method, such as the desired level of service, vegetation, terrain, traffic safety, climate, environment, governing rules and budget.

This study evaluated three different sites and found three different results. The sites varied substantially by vegetation type, density and climate. With all the variables it is difficult to predict results for different areas. As a guideline, expect the following:

- 0 to 4% coverage with 4 treatments per year at sites similar in climate to Site 1.
- 7 to 17% coverage with 4 treatments per year at sites similar in climate to Site 2.
- 4-11% coverage with 6 treatments per year at sites similar in climate to Site 2.
- 8-40% coverage with 4 to 6 treatments per year at sites similar in climate to Site 3.

For characteristics of the three sites see Section 3.1, Section 7.1 and Appendix H.

Some potential areas for infrared use could include the following:

- near waterways
- on Federal or other lands that prohibit herbicides
- use as a growth regulator (e.g. in grassy swales, culvert inlets and ditches)

To aid in the efficient operation of the infrared equipment, obstacles and obstructions should be removed or moved outside the treatment area where possible. Such obstacles include sight posts, sign posts, mailboxes, limbs and rocks.

Based on observations from this study, the following comments and guidelines on infrared vegetation treatment are provided:

- Infrared is effective in "maintaining" vegetation already in a controlled condition.
- It is effective with light vegetation conditions and for suppressing new growth.
- It is less effective in reducing vegetation in dense growth areas.
- This type of treatment may kill some seed types directly exposed to the infrared heat, but it does not appear to kill seeds embedded in the soil or covered by other vegetation.
- It kills runners that enter into the treated area, but does not kill source roots that are outside the treated area.
- Mowing tall vegetation adjacent to infrared treated areas may be necessary to keep vegetation contained, reduce seed spread and maintain safe sight distance.
- Infrared only treats the exposed vegetation; low growing vegetation hidden under taller growing vegetation is protected from the treatments.
- Three to four infrared treatments per year should be sufficient in most conditions and climates where there is light vegetation and low to moderate growth rates.
- For dense vegetation conditions (e.g. vegetation comprised of several layers or bunched tightly together), eight or more infrared treatments may be needed to bring the vegetation under control.
- To reduce costs, dense vegetation should first be controlled by other methods (e.g. shoulder blading or herbicides) prior to infrared treatments.
- To reduce the hazard of fires, vegetation should generally be under 2 in. (50 mm) and low density. Taller vegetation may be acceptable if it has sparse growth. Dense vegetation will eventually dry out and become a combustible source. Mowing tall vegetation prior to infrared treatments may be needed.
- Grasses are generally the first vegetation to appear after an infrared treatment.

9.3 FUTURE CONSIDERATIONS

IVM practices already consider multiple methods to control vegetation. This study, however, did not investigate the effects of combining different treatment methods. Infrared treatments alone may not be practical in all areas, such as the densely vegetated areas of Site 3 or in large areas where costs may become an issue. When combined with other methods, infrared treatments may be practical. The following considerations are offered as future experimental possibilities only, for they were not evaluated as a part of this study.

- Shoulder blading is very effective in controlling dense hardy vegetation. The operation can leave the ground in a barren condition, and vegetation usually does not recur for several months. Cultivated soil is vulnerable to noxious weed invasion, however. A few light infrared treatments may be sufficient to control fragile new seedlings that emerge from this barren condition.

- Herbicides can also be effective in controlling dense hardy vegetation. It also has the benefit of controlling runners that may be rooted outside the treatment area. It can be ineffective, however, on some chemically tolerant plants. Tall dead vegetation that remains after herbicide treatment can also be unsightly if not mowed. Infrared treatments could supplement this method to reduce the chemicals used in an environmentally sensitive area and help control the chemically tolerant weeds. Herbicide treatments could either be scheduled less frequently or applied at a reduced rate when supplemented with infrared treatments.

- Mowing will temporarily control the height of the vegetation, but it is less effective in reducing or controlling the coverage of the vegetation. A low concentration of herbicide can slow the growth rate. Although not tested, several light infrared treatments might have similar effects.

- Vegetation in ditches and grassy swales provides beneficial filtering of runoff water. Dense vegetation can impede flow and trap sediment, though. Infrared treatments could be considered as a growth inhibitor to retain some vegetation and slow the growth rate. Whether such treatments could extend the duration between ditch cleaning operations is not known. From this study, it appears that infrared treatments would preserve more of the grasses than the broadleaf plant species.

- Some culverts are susceptible to clogging from excessive growth at the inlets. This usually occurs in the spring when water is present. The use of pesticides under these conditions can result in pollution hazards. Infrared treatments could be used to eliminate the exposed vegetation, especially in environmentally sensitive areas. Such treatments should be avoided, however, where plastic culvert pipe is used.